National Environmental Satellite, Data, and Information Service

Recent Improvements on AIRS V6-CH4 retrieval, validation and data analysis

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Antonia Gambacorta, Xingpin Liu (NOAA)
Thomas.S.Pagano(JPL), Leonid Yurganov(UMBC)

Thanks all AIRS team since a good retrieval of CH4 relies on a good retrieval of Temp and Wv

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NASA Sounder Science Team Meeting
Nov. 9, 2011, Greenbelt, MD

Outline

- **Recent Improvements for Version 6**

1) **Based on intensive validation using aircraft measurements (esp. HIPPO);**
2) **Through comparison with Optimal-Estimation method(not shown);**

- **Recent Scientific Activities:**

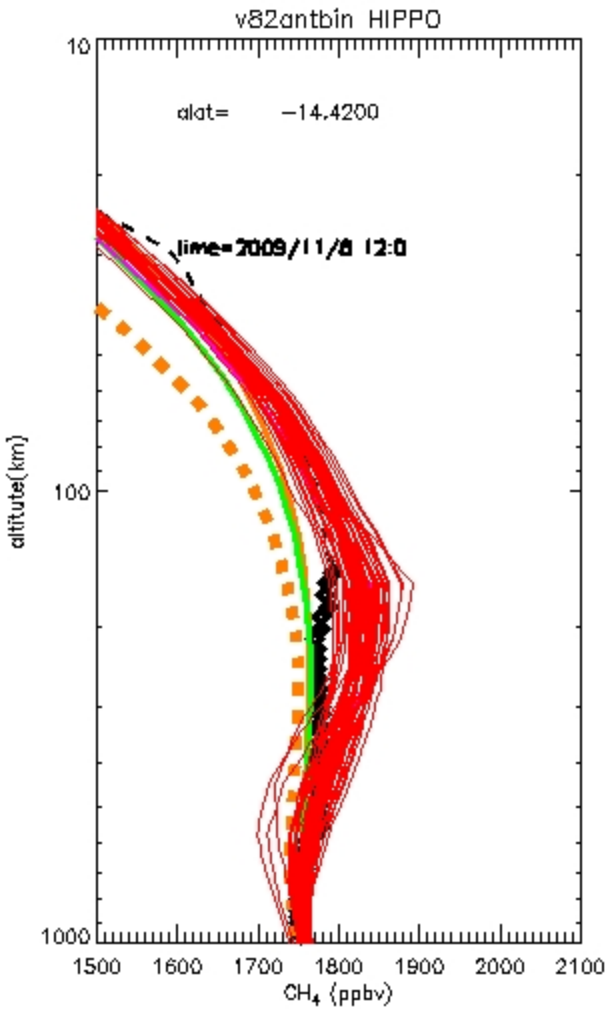
  - with a focus on CH4 in the HNH and recent trend study

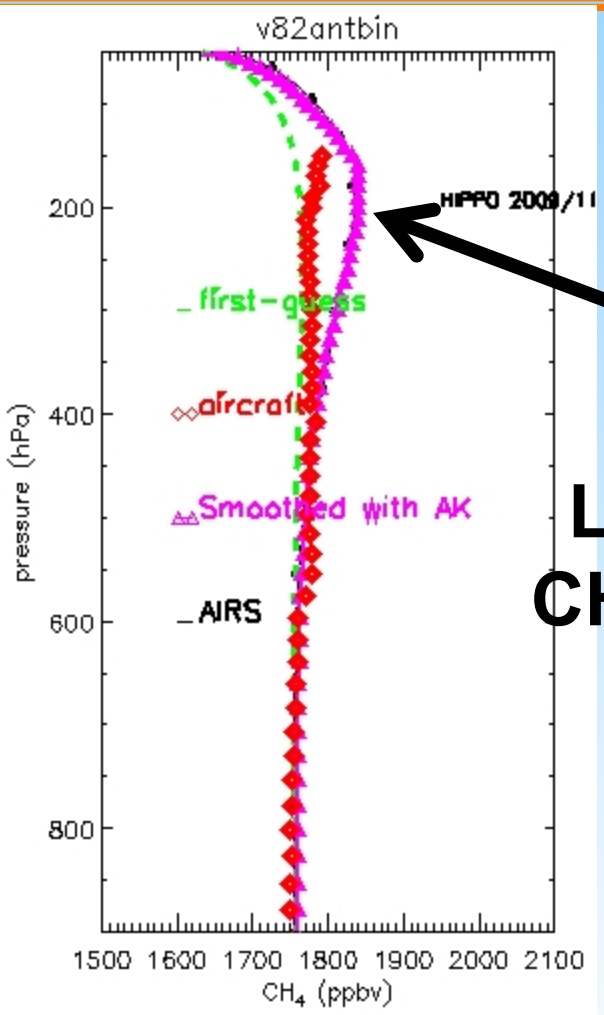
Optimization in AIRS V6 – CH4

- Optimization of first-guess
- Add 3 trapezoid functions (from 7 to 10)
- Channels & damping (adjust accordingly)
- Uncertainty of Spectroscopy in CH4 band and forward model are two major factors impacting CH4 retrieval

1) V5 - a rough tuning to the absorption in CH4 peak channels by 2%
2) V6 – a more careful tuning to CH4 channels by 1%-1.5% (not just peak)

A tropical case → tuning is required

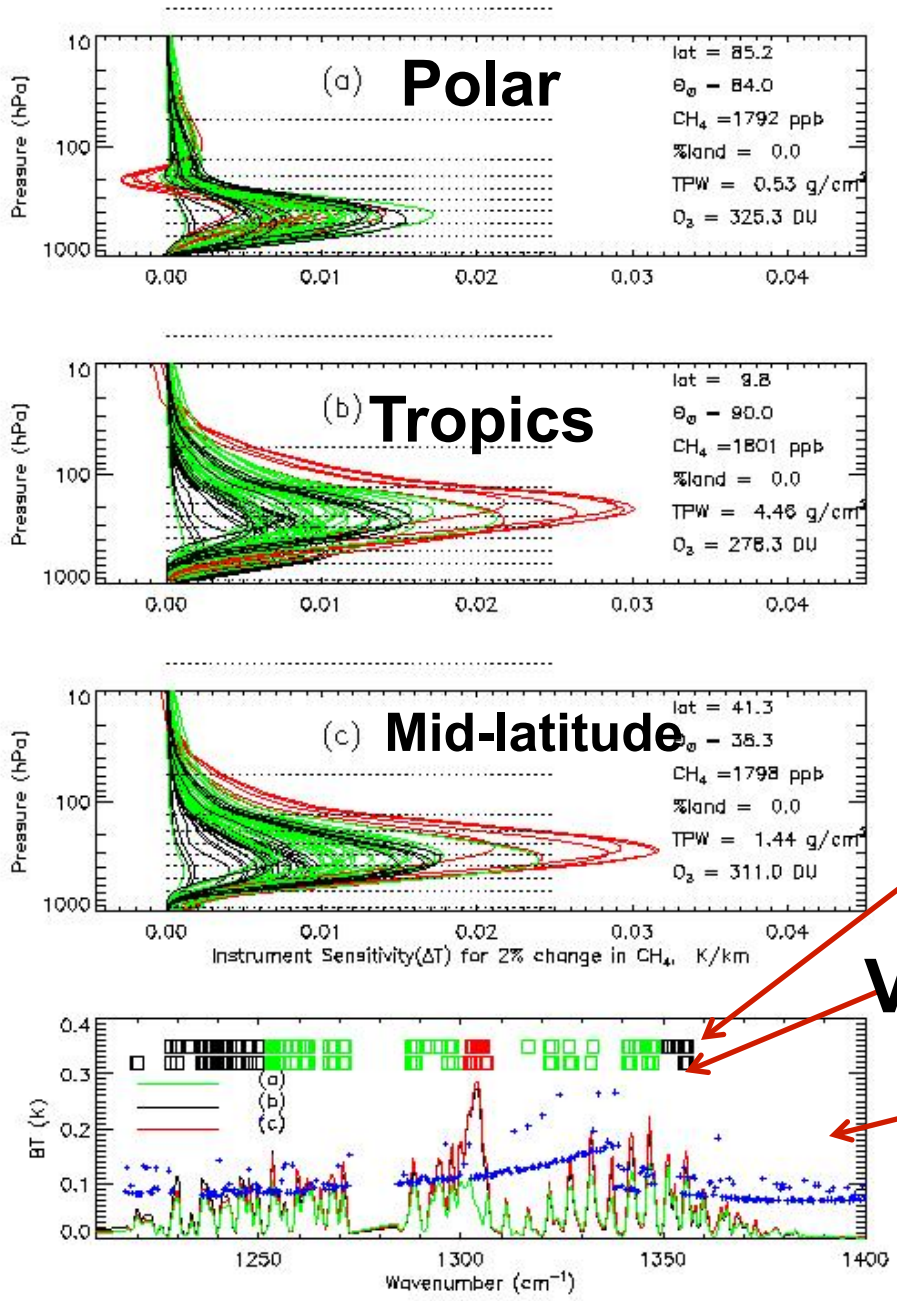




Large increase of CH4 with altitude in tropics ?

Retrieved CH4 (@200 hPa) is obviously larger than observation and forms a bump

AIRS V5→ V6



V5

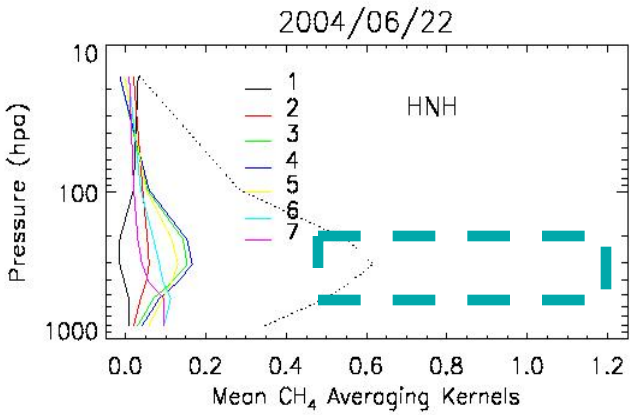
V6

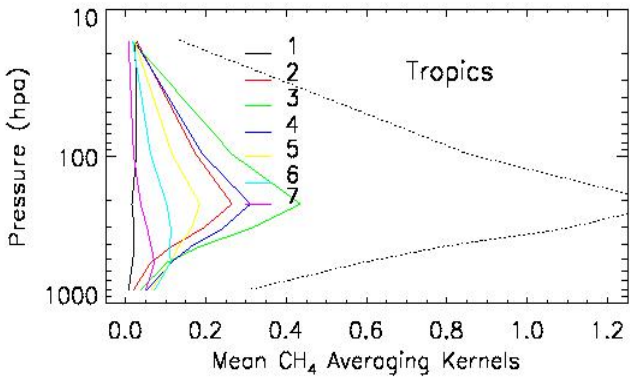
- 7 retrieval layers (V5) --> 10 (V6)
- New channel selection
- Able to resolve 2% change of CH4

V6 has more sensitivity to lower tropospheric CH4

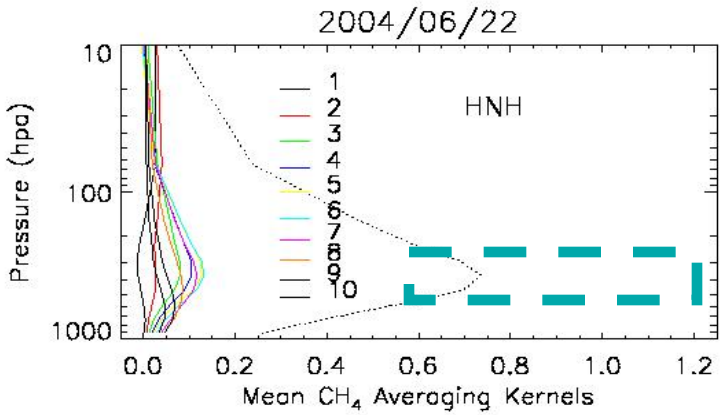
Averaging kernels

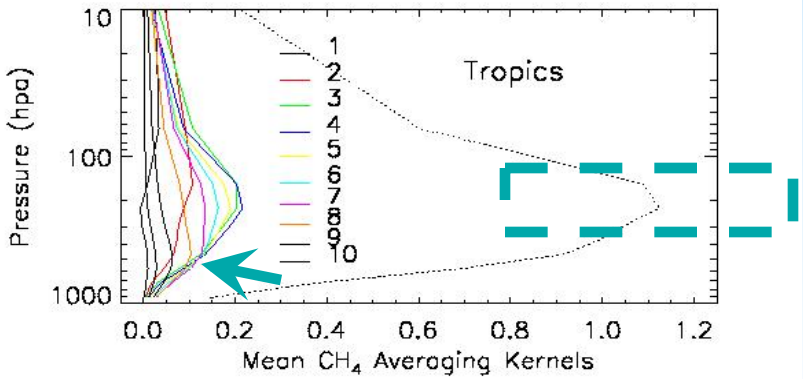
V5





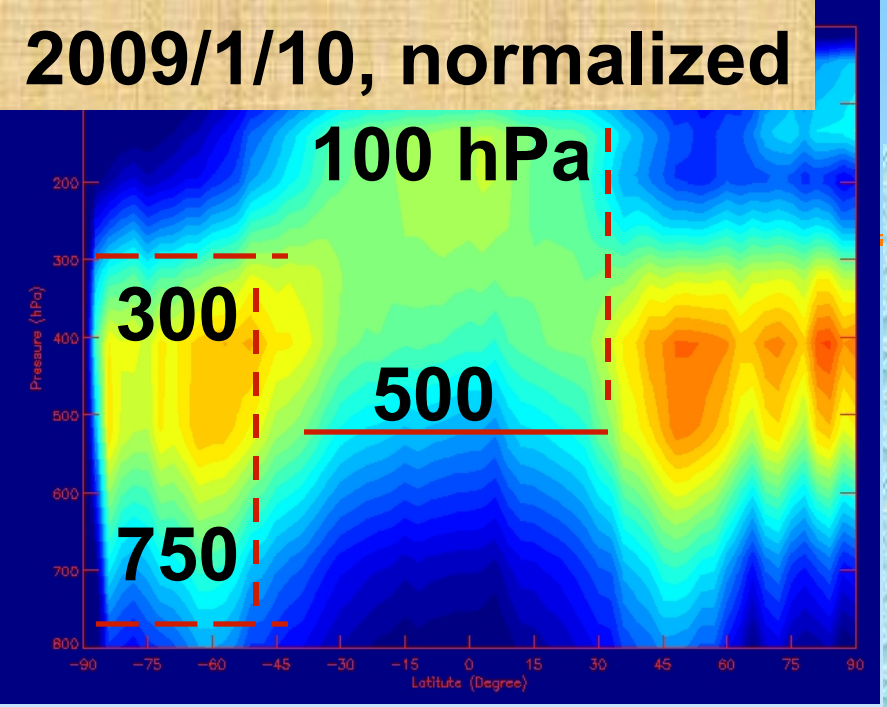
V6



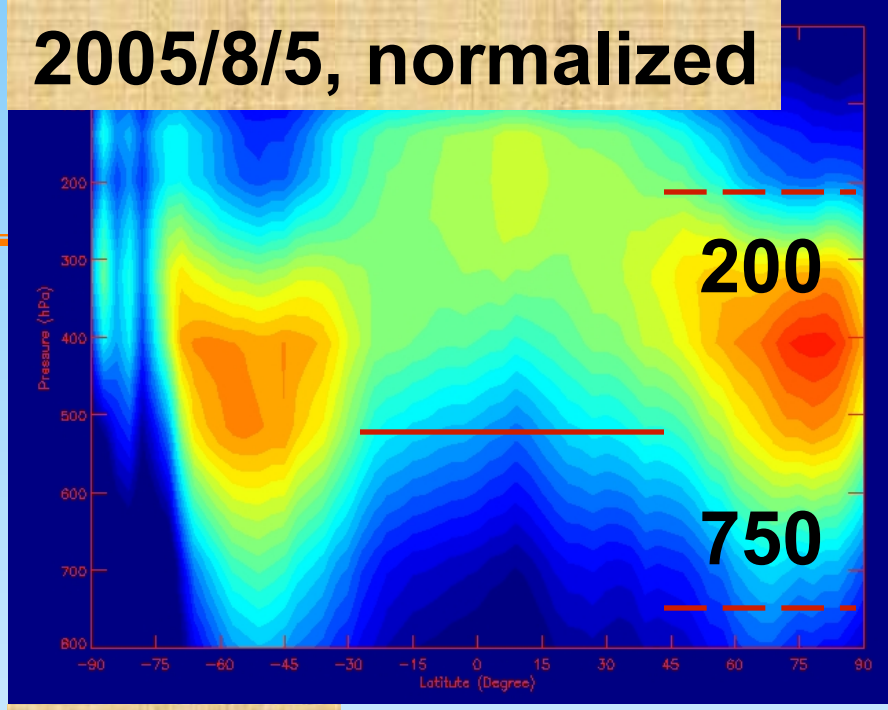


Sensitivity of AIRS CH4(V6)

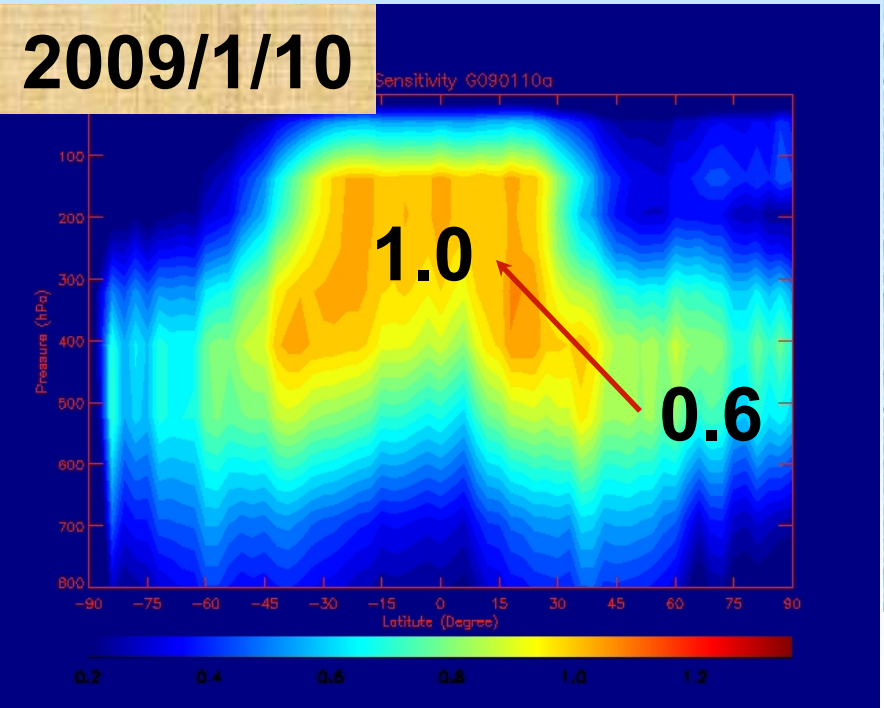
2009/1/10, normalized



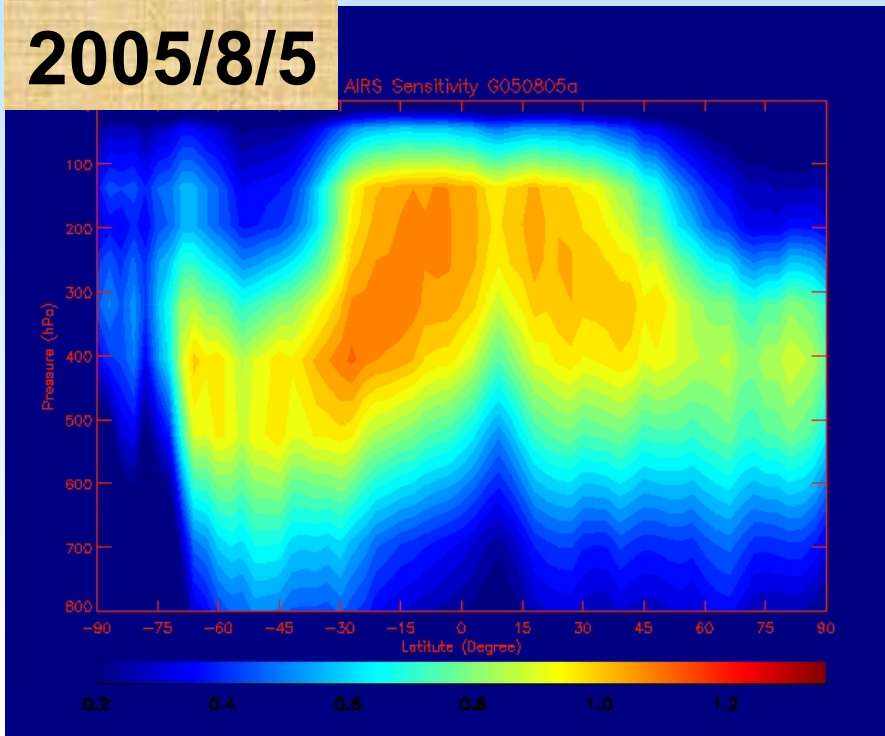
2005/8/5, normalized



2009/1/10



2005/8/5

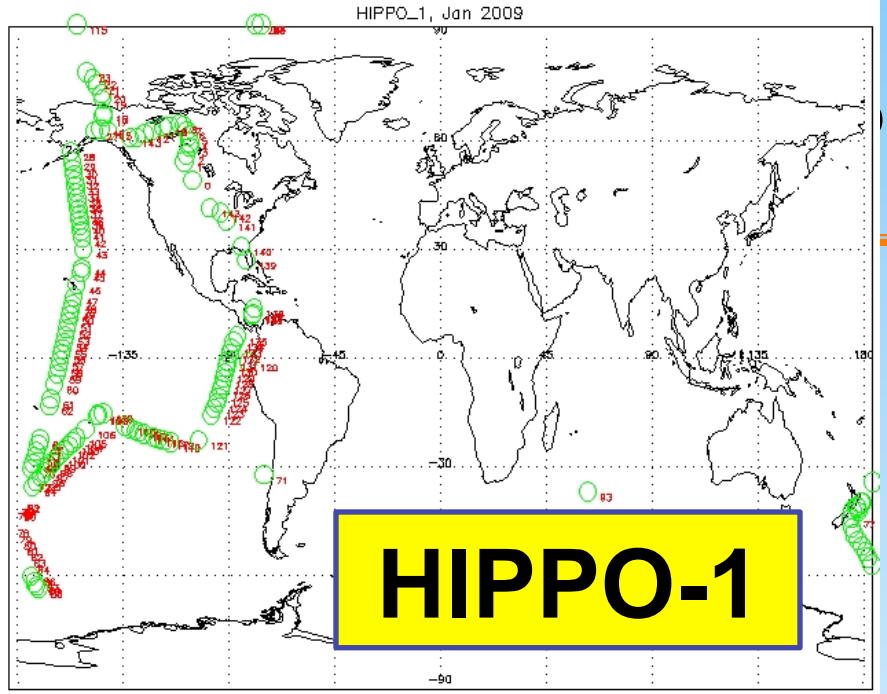


All these improvements in V6 are based on extensive validation

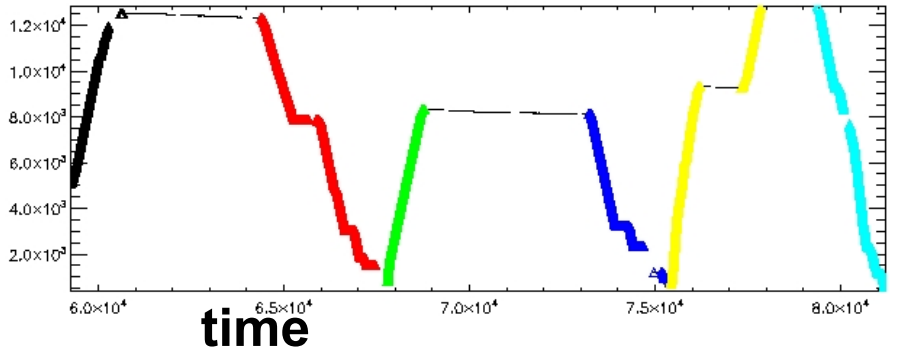
Aircraft measurements used include

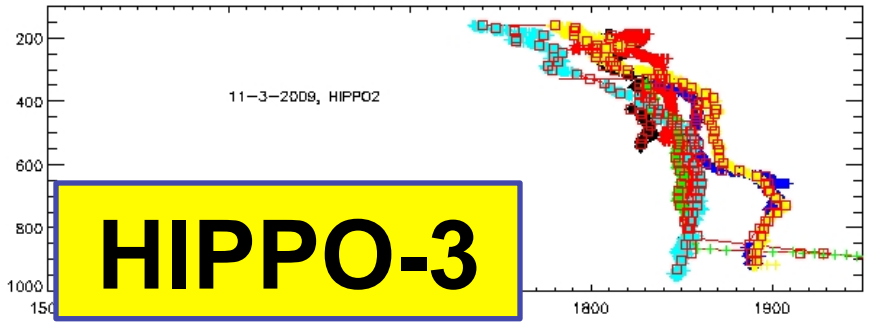
1. Aircrafts measurements from NOAA/ESRL/GMD (the only one used for V5 optimization)
2. Intex-A (2004), -B(2006)
3. START08(2008)
4. ARCTAS(2008)
5. HIPPO-1, -2(2009), -3(2010)

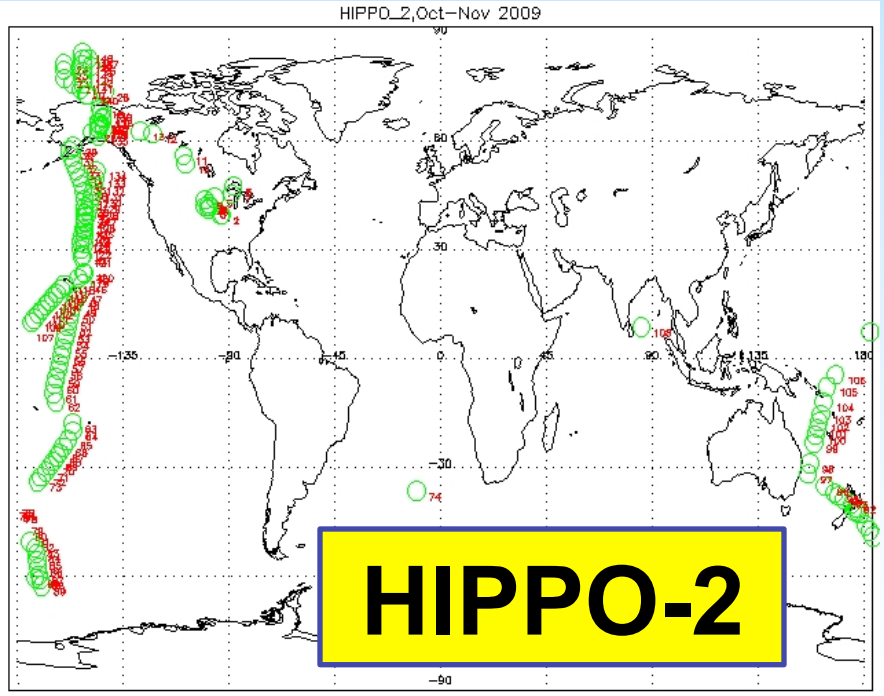
   HIPPO-4, -5 data have not been released to public

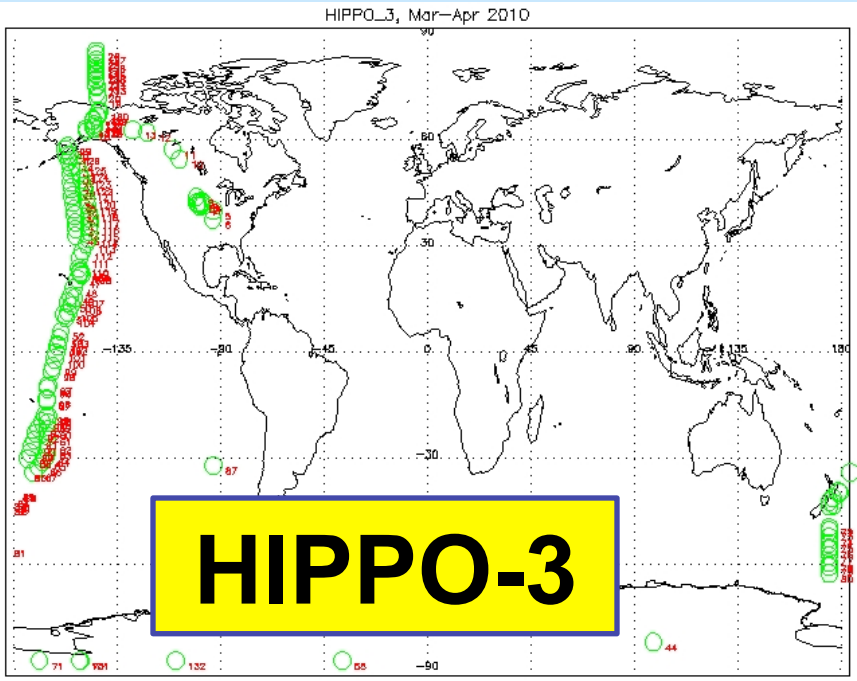

HIPPO_1, Jan 2009
HIPPO-1

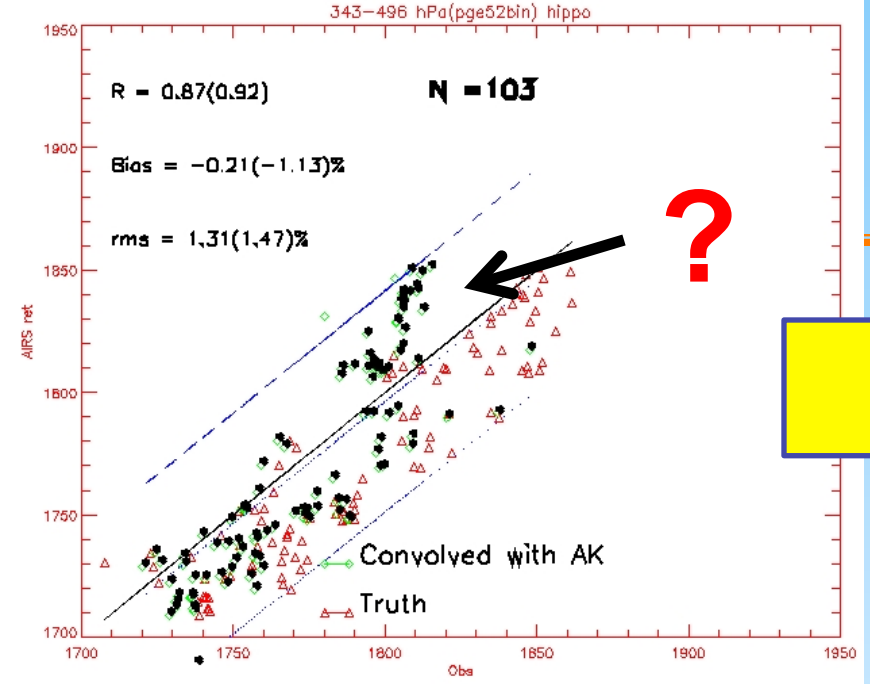
PC


time

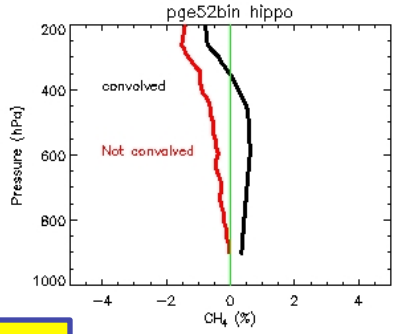

11-3-2009, HIPPO2
HIPPO-3

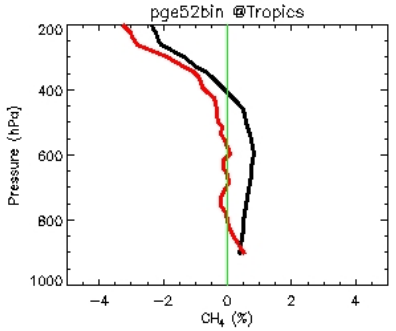

HIPPO_2,Oct-Nov 2009
HIPPO-2

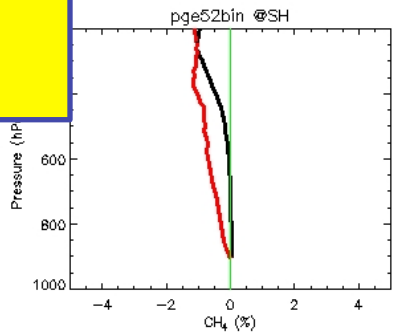

HIPPO_3, Mar-Apr 2010
HIPPO-3

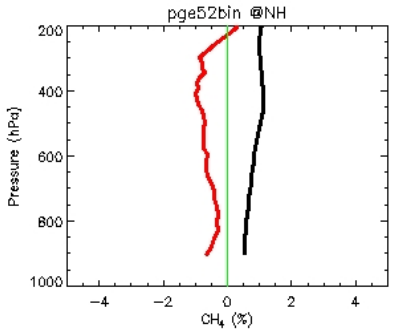

343–496 hPa(pge52bin) hippo
R = 0.87(0.92)
N = 103
Bias = −0.21(−1.13)%
rms = 1.31(1.47)%
?
Convolved with AK
Truth
AIRS ret
Obs

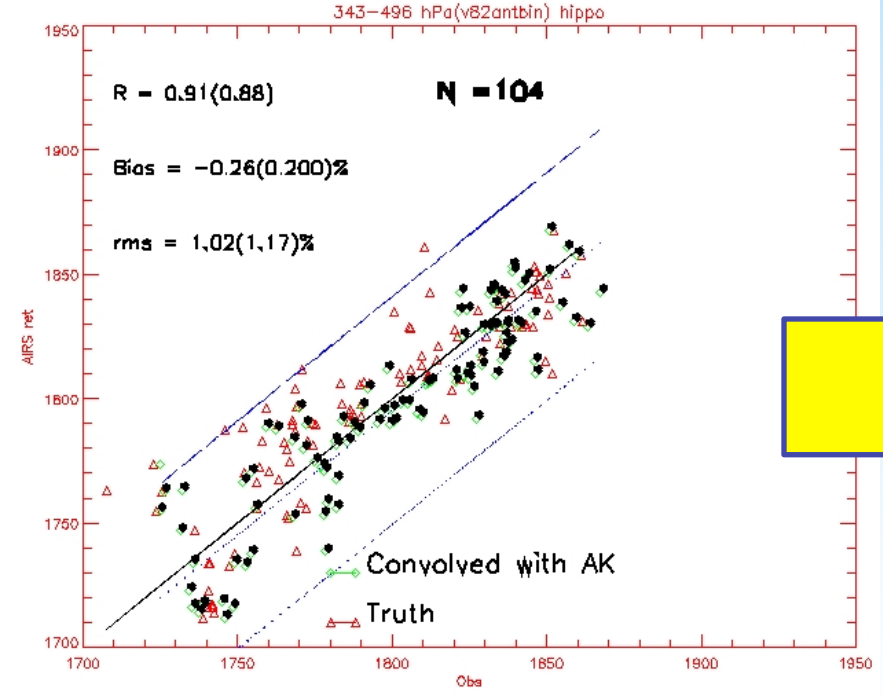
V5


pge52bin hippo
convolved
Not convolved
Pressure (hPa)
CH4 (%)

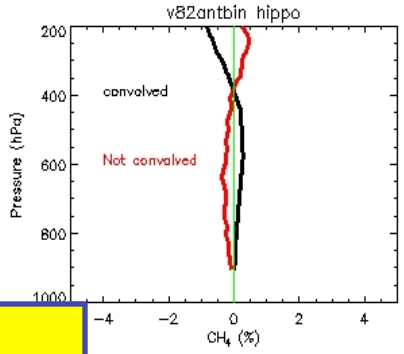

pge52bin @Tropics
Pressure (hPa)
CH4 (%)

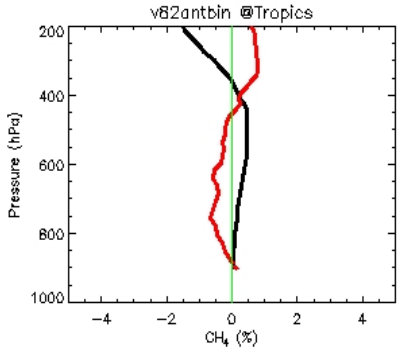

pge52bin @SH
Pressure (hPa)
CH4 (%)

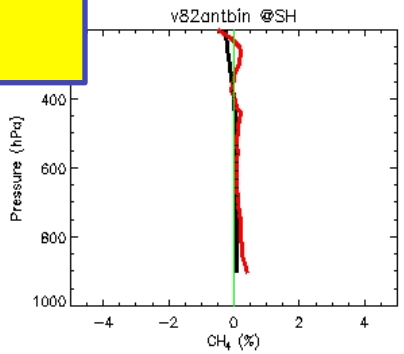

pge52bin @NH
Pressure (hPa)
CH4 (%)

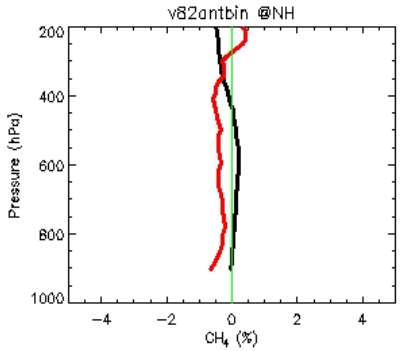

343–496 hPa(v82antbin) hippo
R = 0.91(0.88)
N = 104
Bias = −0.26(0.200)%
rms = 1.02(1.17)%
Convolved with AK
Truth
AIRS ret
Obs

V6


v82antbin hippo
convolved
Not convolved
Pressure (hPa)
CH4 (%)


v82antbin @Tropics
Pressure (hPa)
CH4 (%)


v82antbin @SH
Pressure (hPa)
CH4 (%)


v82antbin @NH
Pressure (hPa)
CH4 (%)

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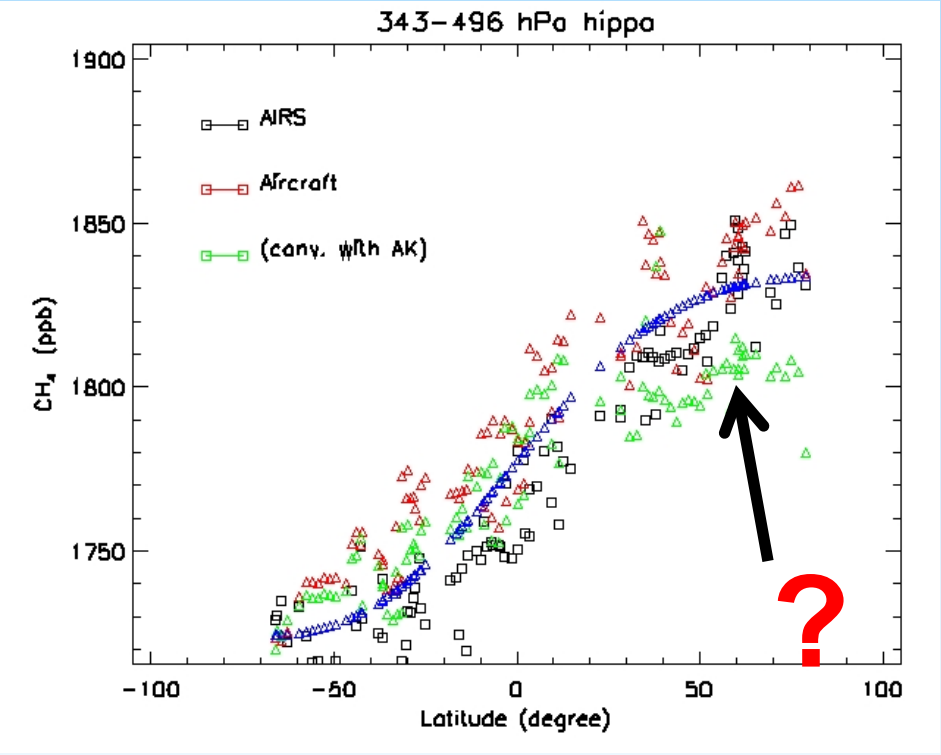
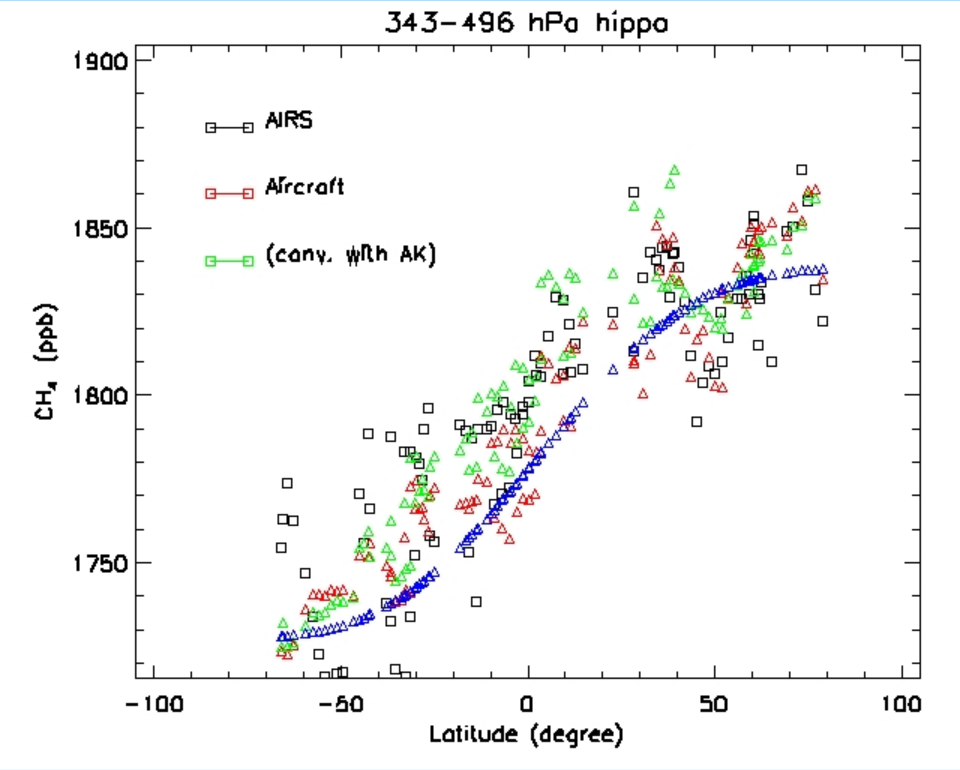
Comparison of Latitudinal Gradient (343-493 hPa) in V5, V6 (HIPPO-1, 2009/01)

V5



V6



Current tuning was mainly based on HIPPO-1 data

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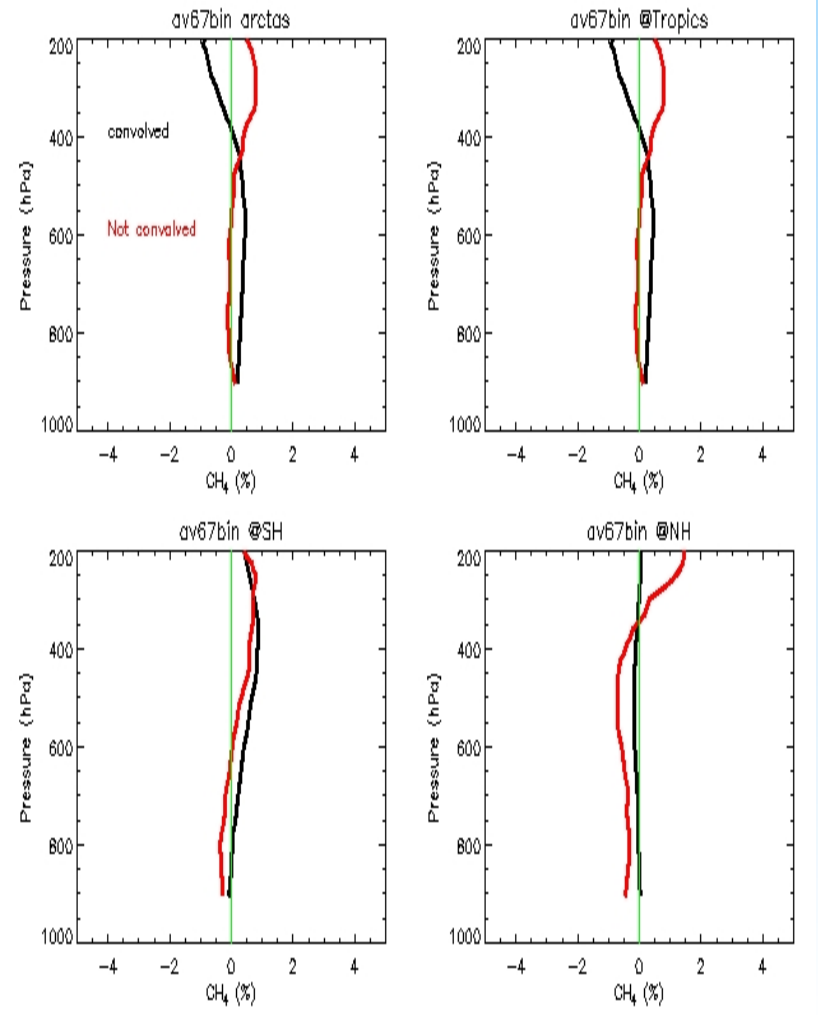
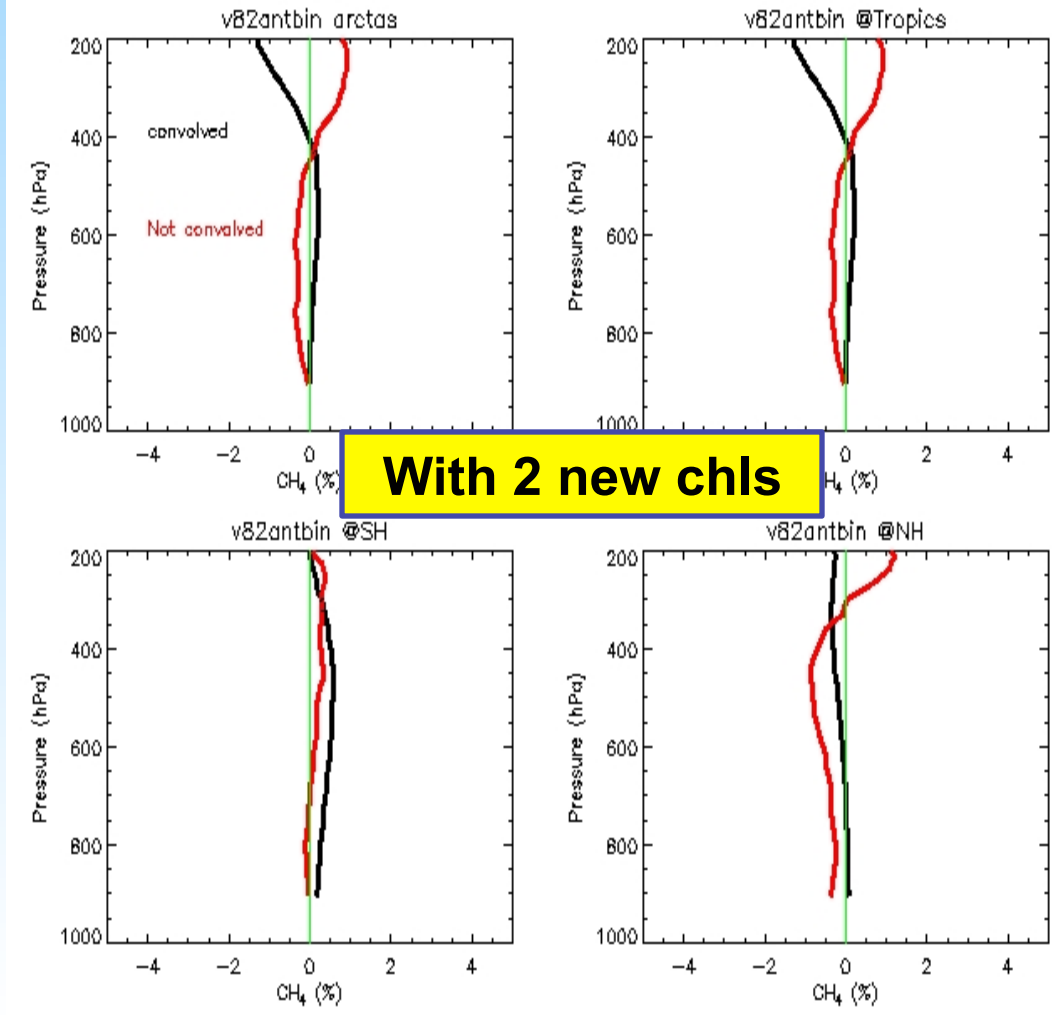
Maybe better to add two more channels in V6, but need more check using HIPPO-2,-3,-4,-5 data

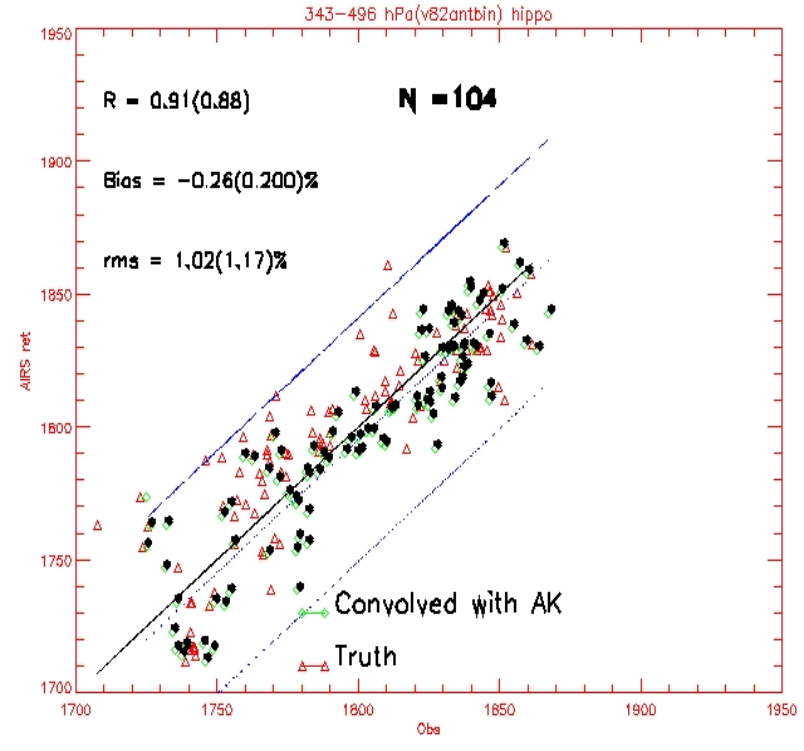
In the past 1 month, we focus on the tuning and validation using more aircraft data from Prof. Steven Wofsy (Harvard Univ.);We took back two channels near the Q-branch, and the results are *slightly better.*

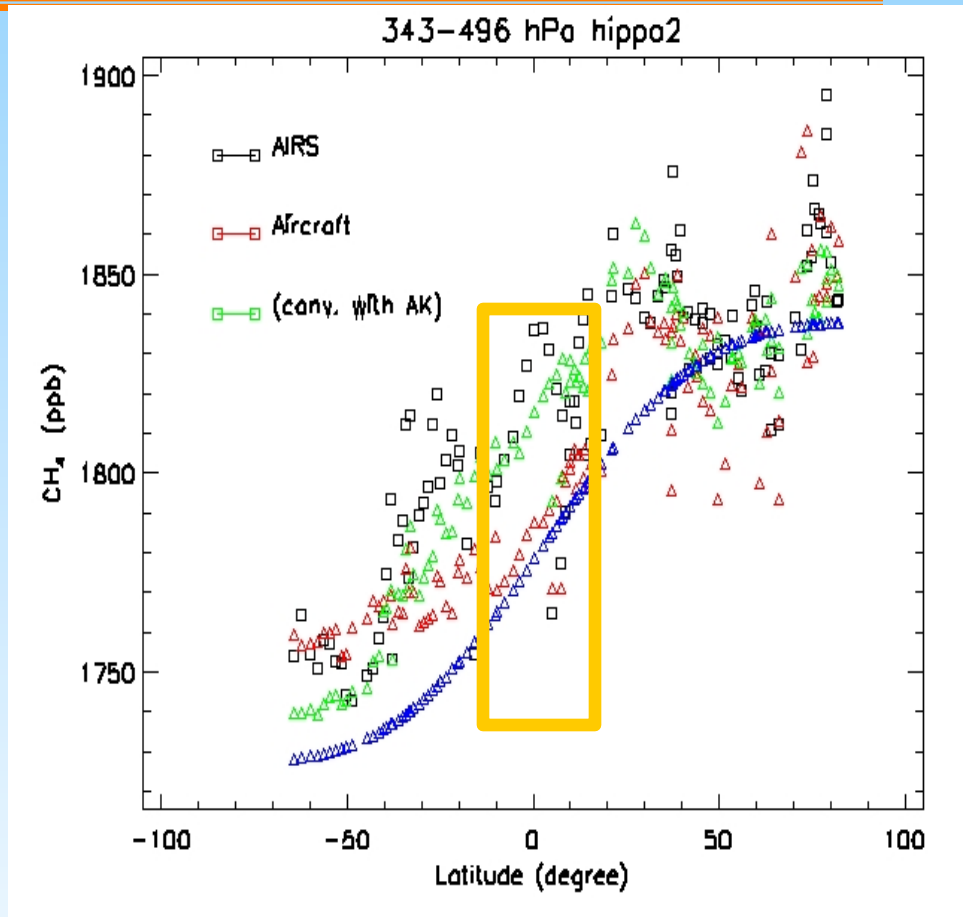




Validation of CH4-V6

HIPPO-2



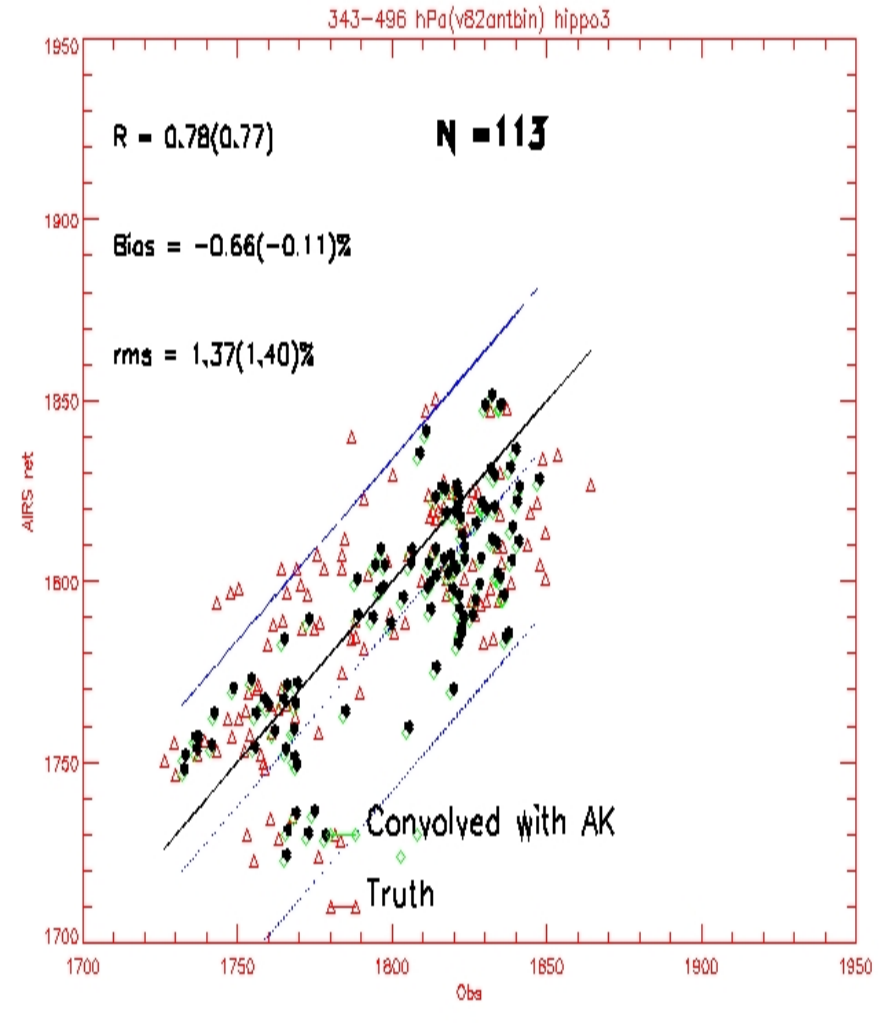


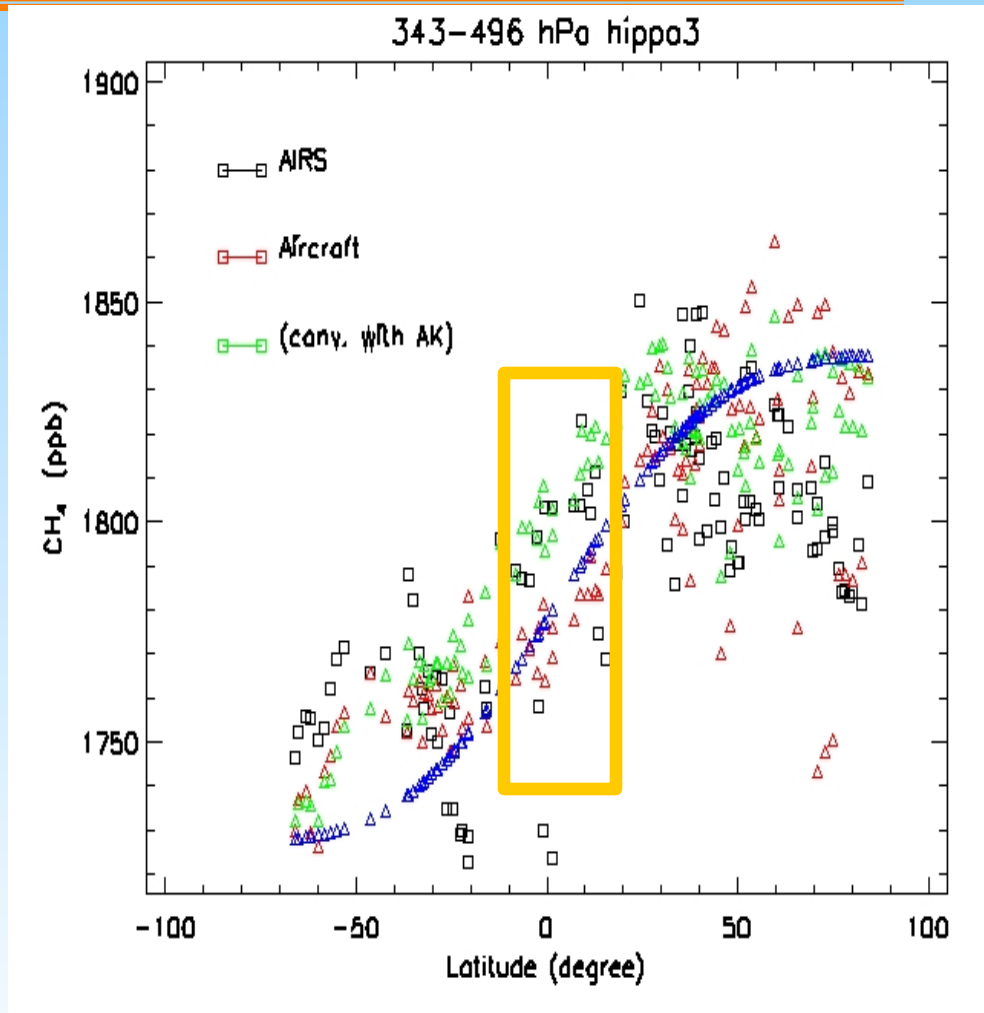
2009/10, 2009/11

In tropics, AIRS-CH4 is higher than in-situ observation, but agree with obs-convolved with AK

Validation of CH4 V6

HIPPO-3





2010/03, 2010/04

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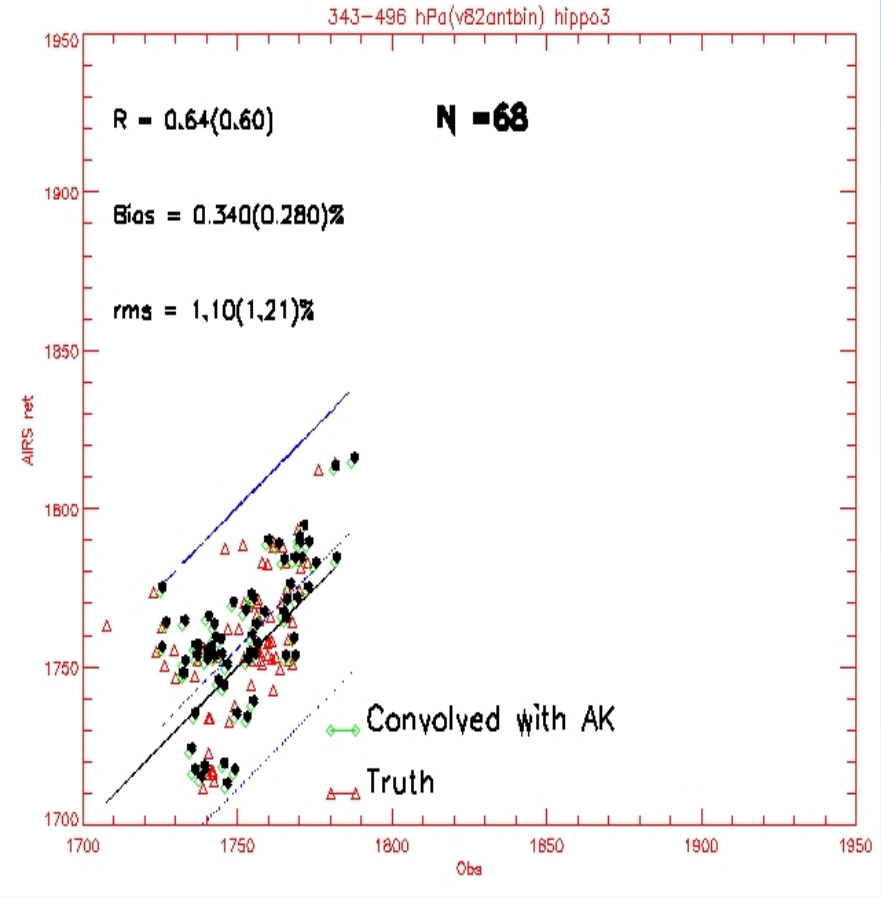
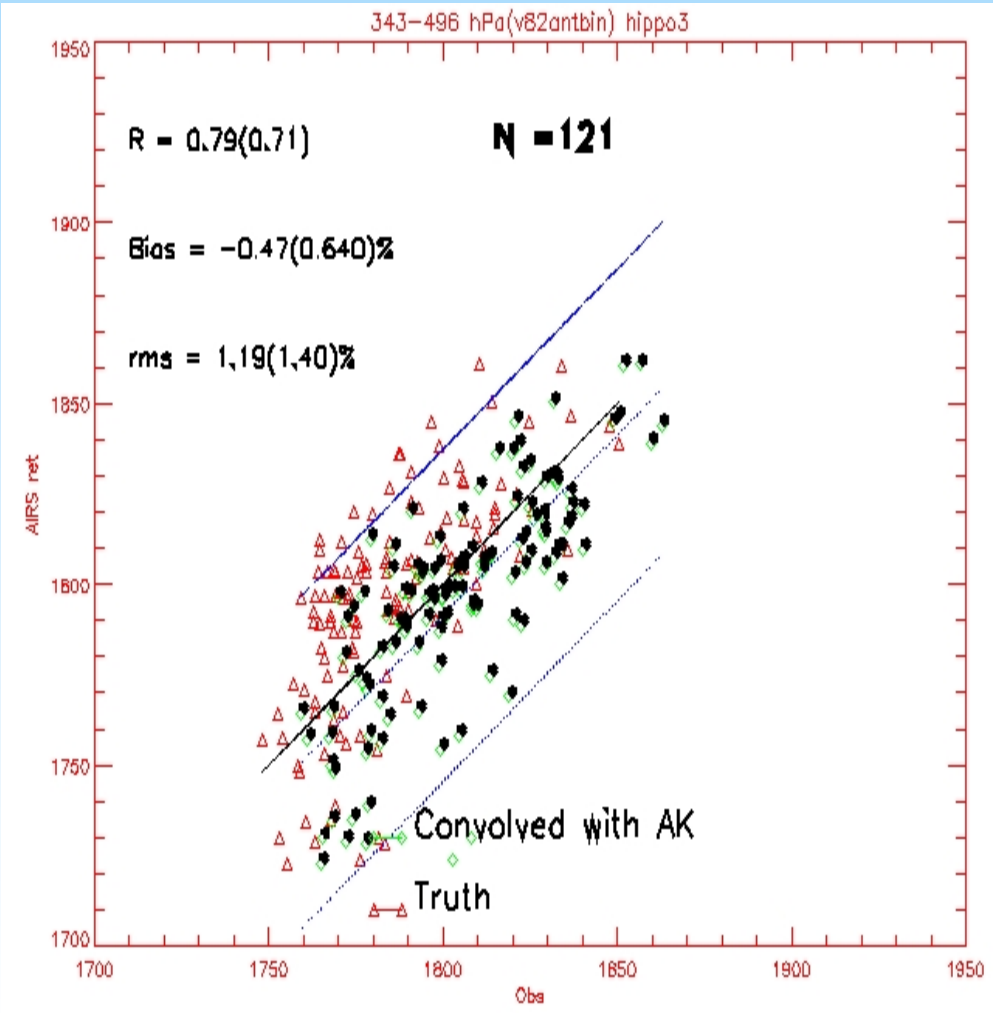
Validation in V6 (using HIPPO-1,-2,-3)

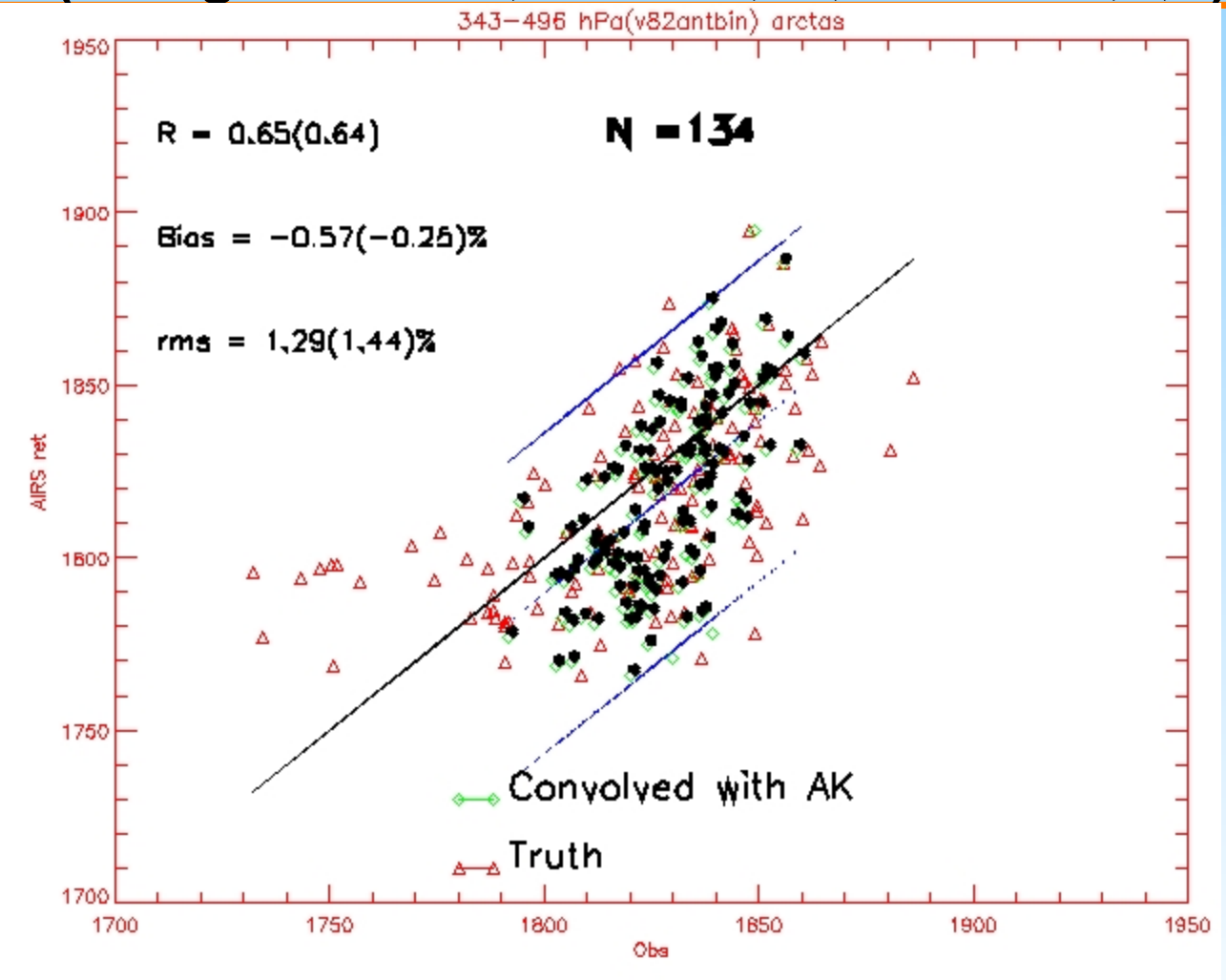
90-30 ºS



30S to 30 ºN

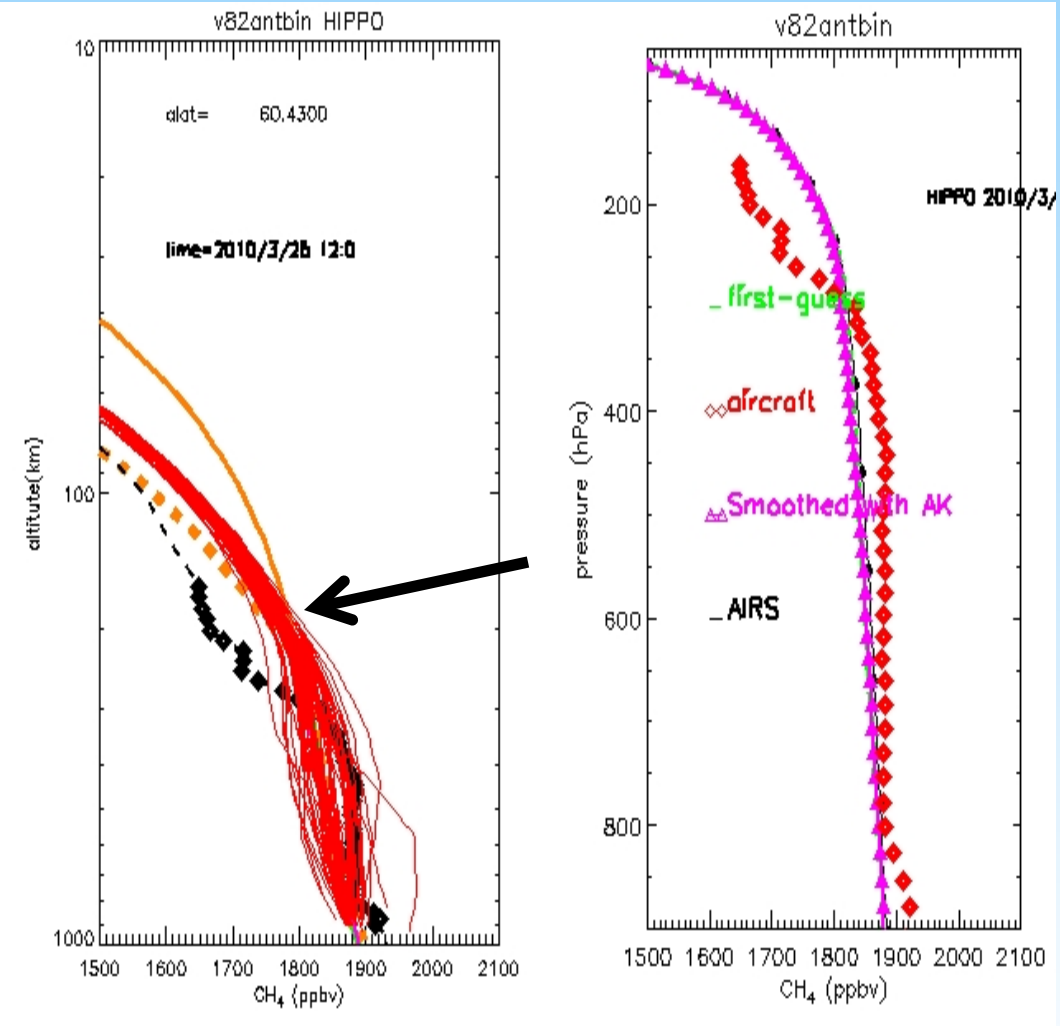


HNH (55N-90N)
(using ARCTAS, Intex-A,-B, HIPPO-1,2,3)



Due to the lower information content, correlation in high latitude is smaller than in tropics

Any more problems ?



During stratosphere intrusion in the HNH, retrieval has a larger bias

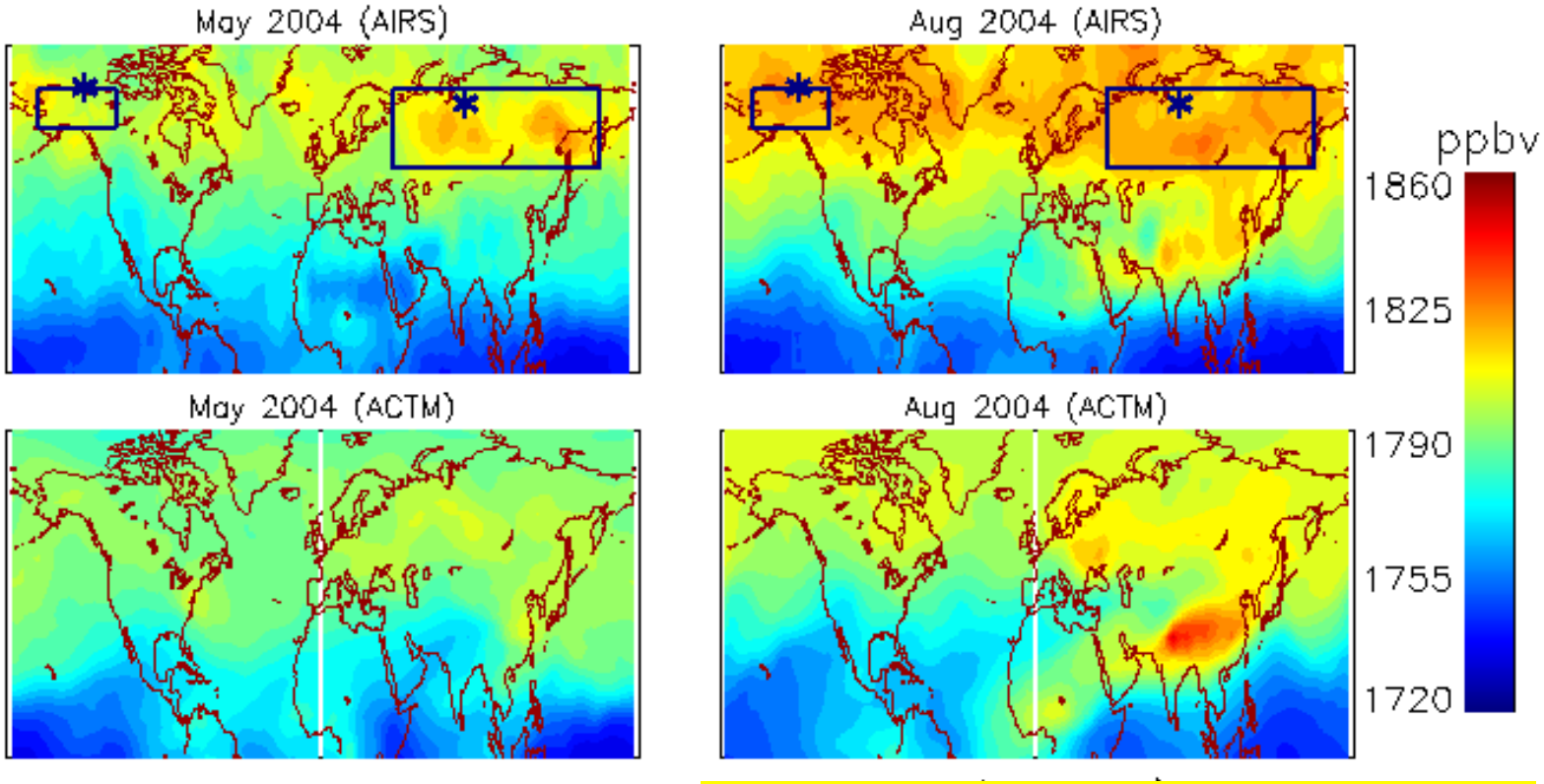
One possible way to fix this problem is to modify the firstguess according to the tropopause height – need more investigation → V7

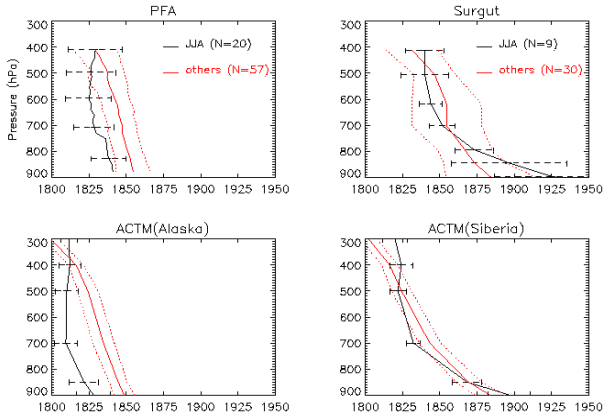
Recent Scientific activities since last Meeting → promote the use of AIRS CH4 products

1. IWGGMS-7, May 16, 2011,Edinburgh, UK (no money to travel, presented by Tom Pagano, and missed the GOSAT PI meeting followed IWGGMS-7).
2. In close contact with GOSAT team and plan to co-author a paper on the comparison of AIRS CH4 and GOSAT-CH4 product.
3. One Ph.D thesis in Purdue University to assimilate AIRS CH4 data in model simulation and a paper is in preparation (just graduated) and NOAA/ESRL expressed their interest to assimilate AIRS CH4 in CarbonTracker model.
4. Leonid and myself are in closely contact with Prof.Steven Wofsy (Harvard Univ.) , who is very interested in comparing AIRS CH4 with HIPPO measurements → Comparison using V5 data is promising and looking forward to V6 data.
5. K. Walter in UAF has one project about Arctic CH4 study granted by NASA (ROSE) in 2010, AIRS CH4 data was proposed to use (we are a unfunded collaborator).
6. Leonid gave a presentation at *Arctic Methane Workshop, London, 15 Oct.2011.*
7. Paper (by Xiong et al.) was just accepted in the proceeding of 10th International Conference on Permafrost (June 2012, still have not found travel money).

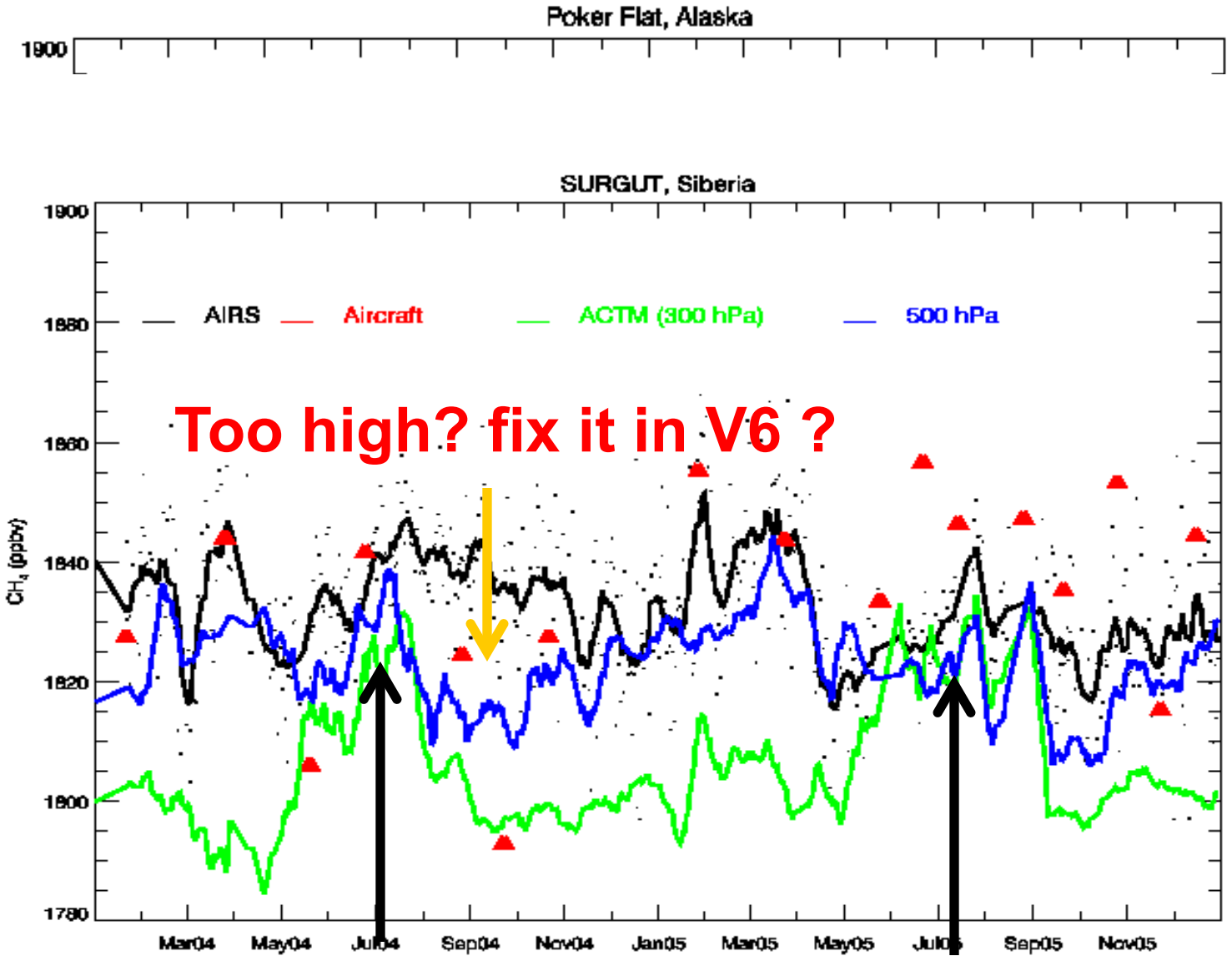
Thermal Infrared Sounder, like AIRS and IASI, CrIS are pretty valuable in space-borne observation of CH4 in the polar regions as:

- ARCTIC is a huge “carbon” pool and vulnerable to climate warming
- Space-borne measurement by NIR is not efficient in the polar region
- Lidar observation from space is promising but still under development

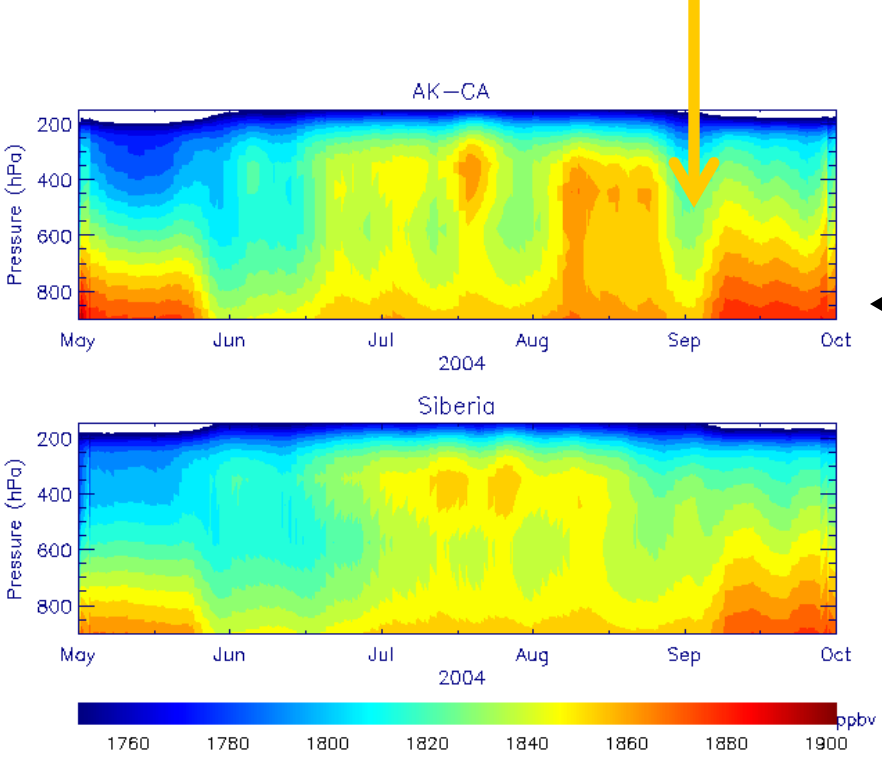




•**Xiong, X., Barnet, C.; Zhuang, Q.; Machida, T.; Sweeney, C.; Patra, P.K., 2010,Mid-upper Tropospheric Methane in the High Northern Hemisphere: Space-borne Observations by AIRS, Aircraft Measurements and Model Simulations, *J. Geophys. Res.*, 115, D19309**, doi:10.1029/2009JD013796.



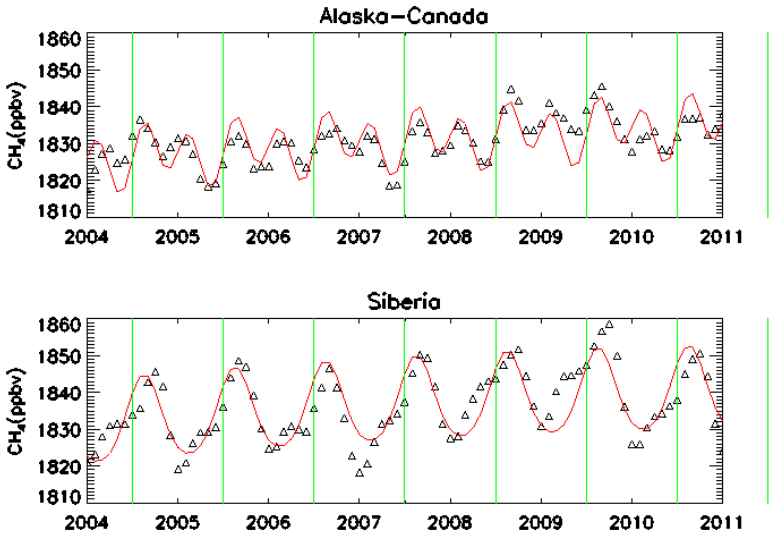
High CH4 in summer



Summer of 2004, from "V6" (NOAA)

more features in lower troposphere

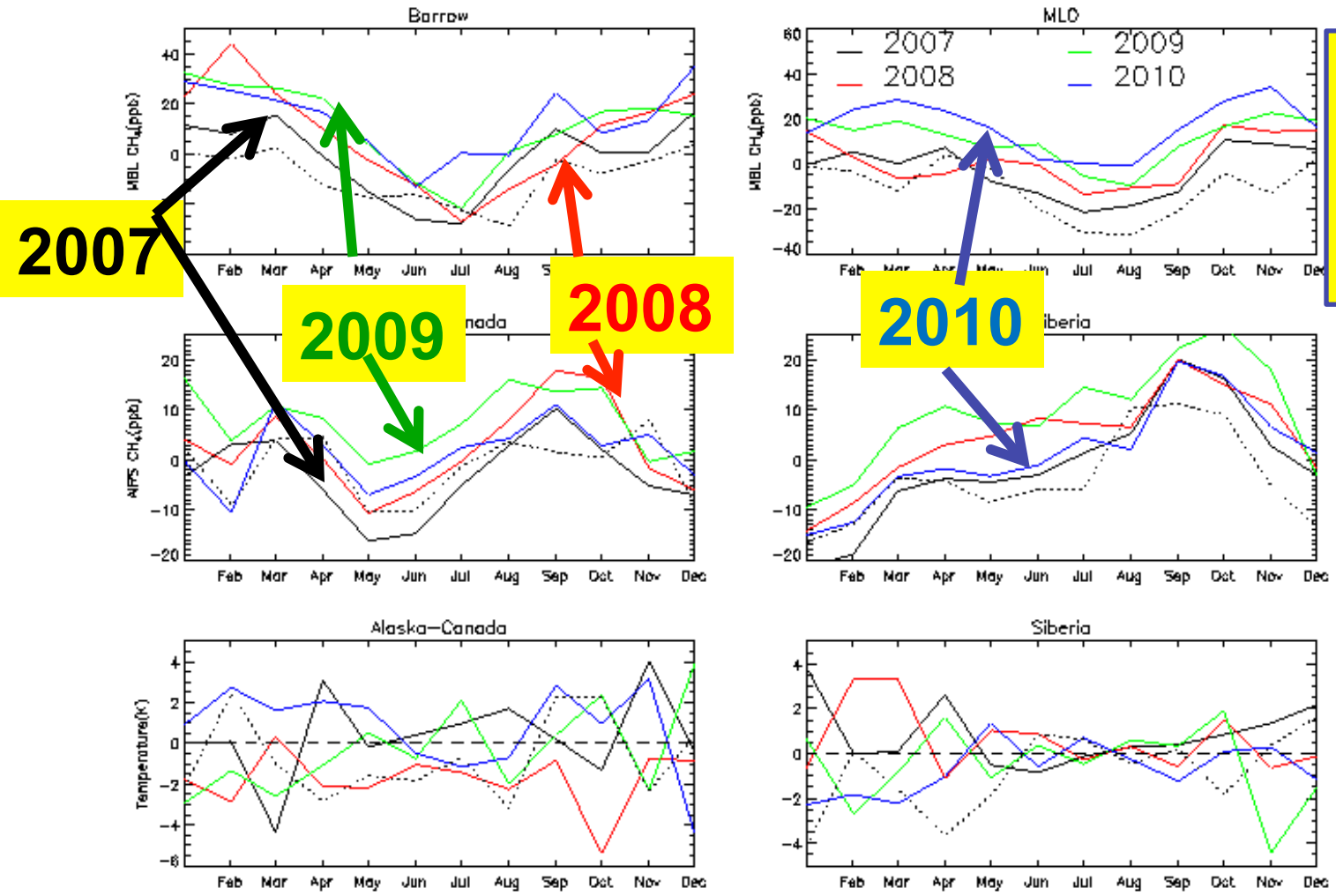
From May to Sept, 2004



Xiong, X., T. Zhang, E. Maddy, Q. Zhuang, C.D. Barnet, Atmospheric Methane in the High Northern Hemisphere and its Relation with Permafrost *Proceedings of the Tenth International Conference on Permafrost*, Russia, 2012 (accept).

significant increase of CH4 occurs in 2008 and 2009

CH4 anomaly from 2006 to 2010



MBL, increase from 2007 to 2009/2010

AIRS increase from 2008 to 2009

Ts warm summer in 2007, AK

significant increase of CH4 occurred in 2008 and 2009 (AIRS)
Increase of surface CH4 started in 2007, continued in 2008-2009, even in 2010 in tropics

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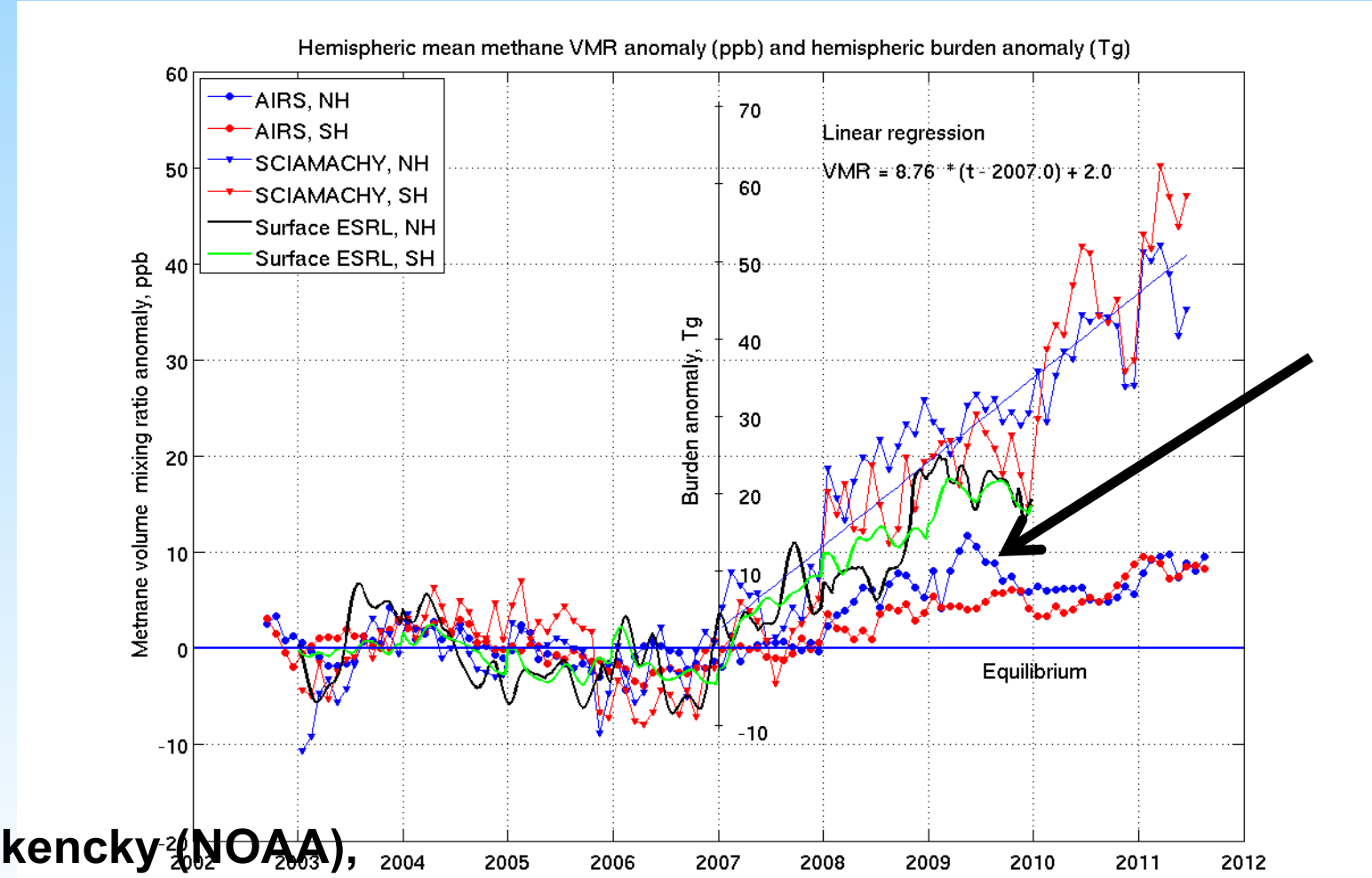
Satellite- and surface-based anomalies of CH4 in ppb (left scale) and in Tg of CH4 (right scale) for troposphere of each hemisphere. Reference period between 2003 and 2007. Global burden anomaly is the sum of Northern and Southern anomalies.



Courtesy
Ed Dlugokencky (NOAA),
Christian Frankenberg (JPL),
Remco Scheepmaker (SRON)

Arctic Methane Workshop, London, 15 October 2011, Leonid Yurganov et al.

Summary

1. Improvement in V6-CH4 have been made under extensive validations. It has better sensitivity to a lower tropospheric CH4 than V5, i.e. 200-500 hPa in tropics and 300-750 hPa in polar, and better accuracy (<1.5%);

2. The recent CH4 increase since 2007 is observed from AIRS measurement, however the significant increase occurs in 2008, 2009 – one year delay than surface CH4.

3. Our studies highlight the value to use TIR to measure CH4 over HNH, in which the emission from wetland and thawing permafrost are large but other observations (NIR from space and ground-based) are difficult.

Acknowledgement

•Thanks to Steven C. Wofsy (Harvard University) and HIPPO team to provide HIPPO data;

•Also thanks the teams of INTEX-A, –B; START08; ARCTAS for sharing their aircraft measurements.

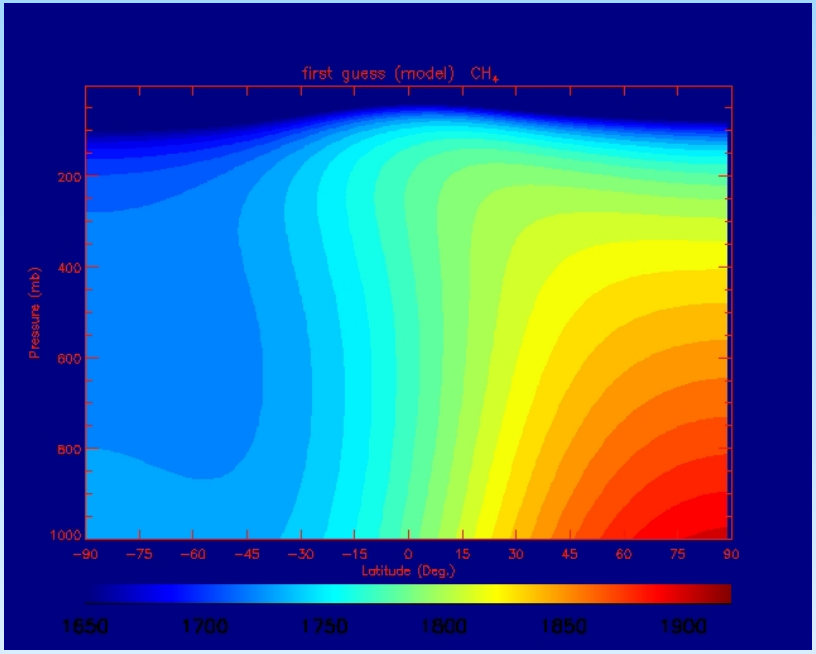
We tried hard and are almost volunteering to improve AIRS V6-CH4 retrieval and validation, and promote the use of AIRS CH4 products (pretty well accepted!),

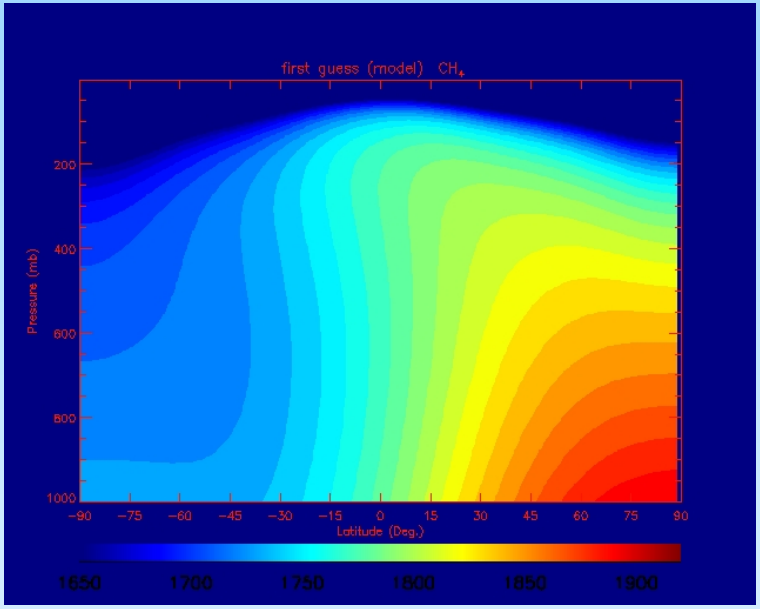
but are facing a problem of no-funding support.

Acronym

- **INTEX** Intercontinental Chemical Transport Experiment: The first phase (INTEX-A) was completed in the summer of 2004 and the second phase (INTEX-B) was performed in the spring of 2006.
- **HIPPO:** HIAPER Pole-to-Pole Observations of Carbon Cycle Greenhouse Gases study (phase 1 --Jan 2009).
- **START08 (Pre-HIPPO) :** Stratosphere-Troposphere Analyses of Regional Transport (1 April to 16 May and 16 to 28 June, 2008).
- **ARCTAS** (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites): March, April, June, and July, 2008.

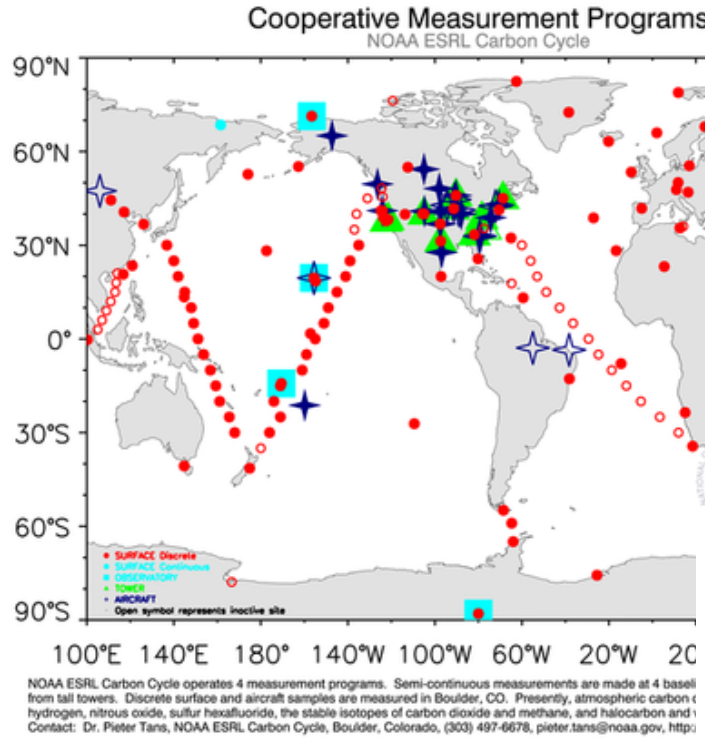
Ch4 firstguess Optimization



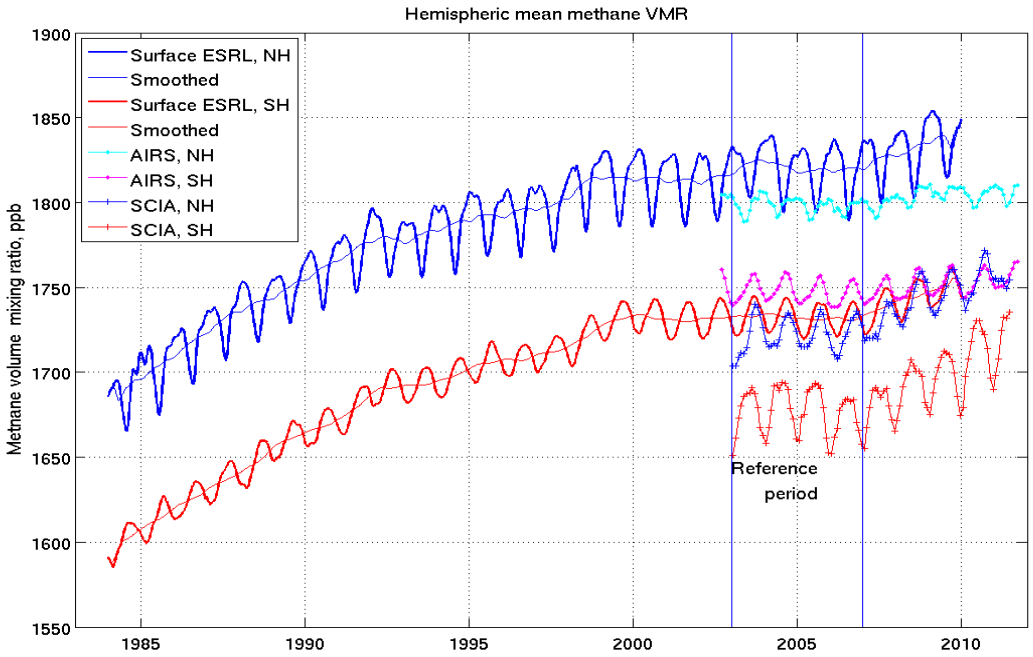


CH4 firstguess is a smoothed function of latitude and pressure, and is obtained through a polynomial fitting to observation and model data

Model data



NOAA/ESRL is the most reliable record of surface CH4. Results of CH4 sampling near the surface at the sites indicated are averaged



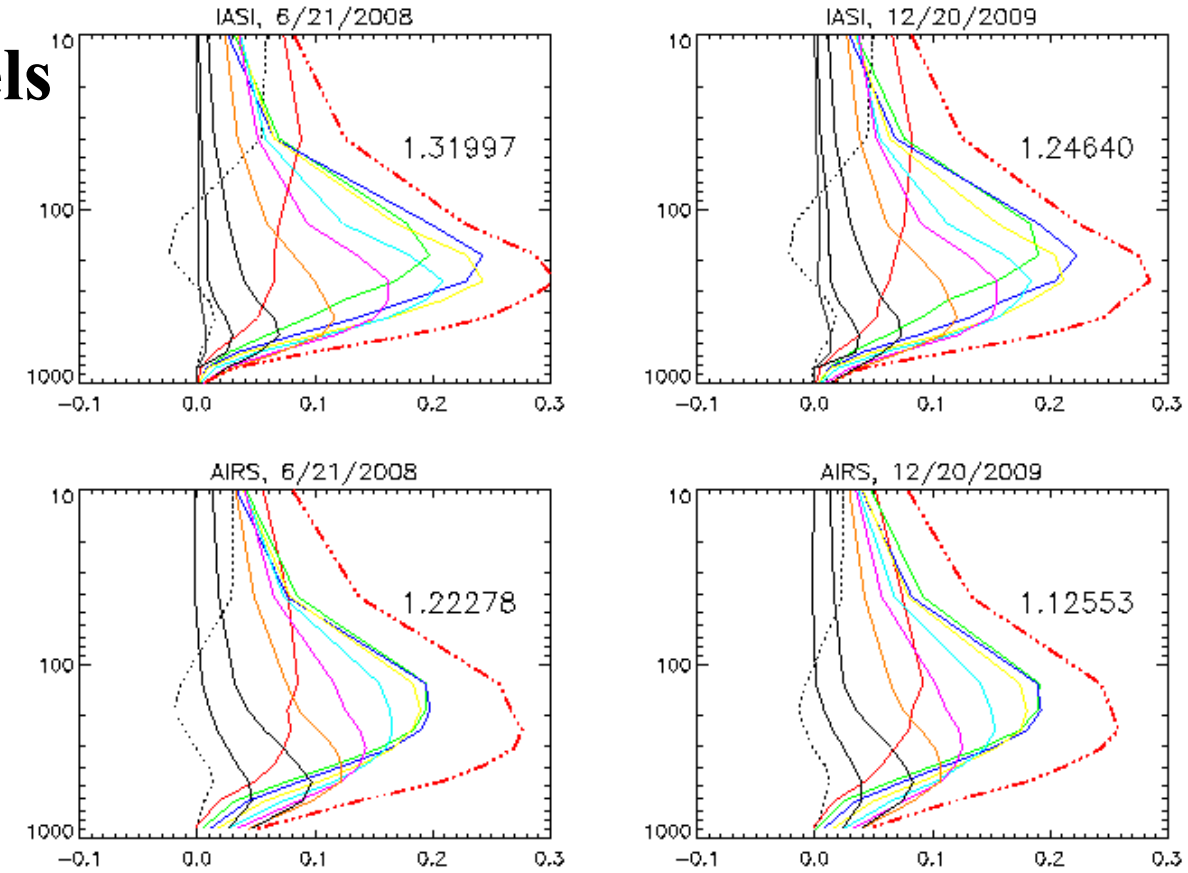
Courtesy Ed Dlugokencky (NOAA), Christian Frankenberg (JPL),

IASI has more channels, the DOF is slightly higher than AIRS (but it depends on the optimization to the algorithm)

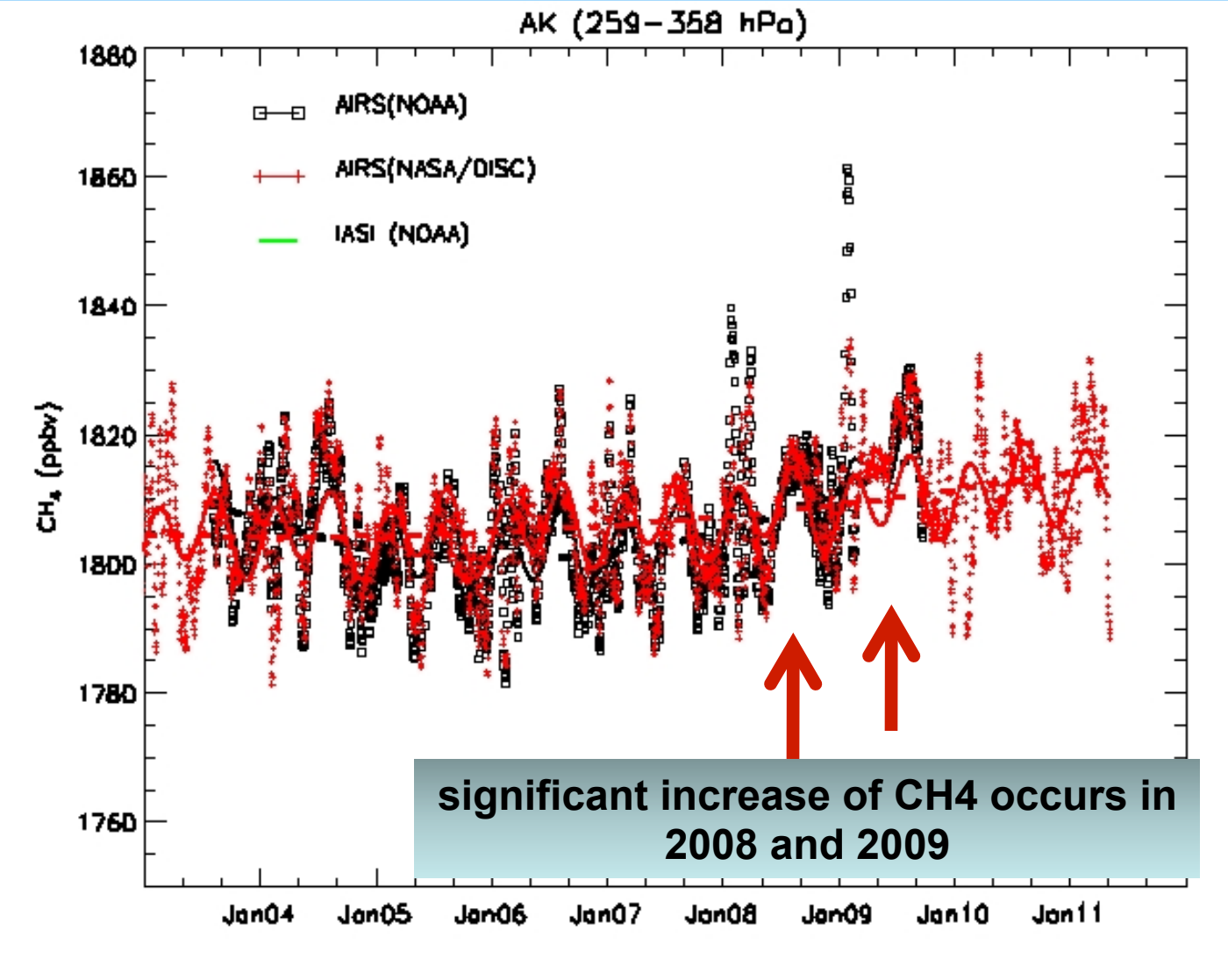
Averaging Kernels

IASI →

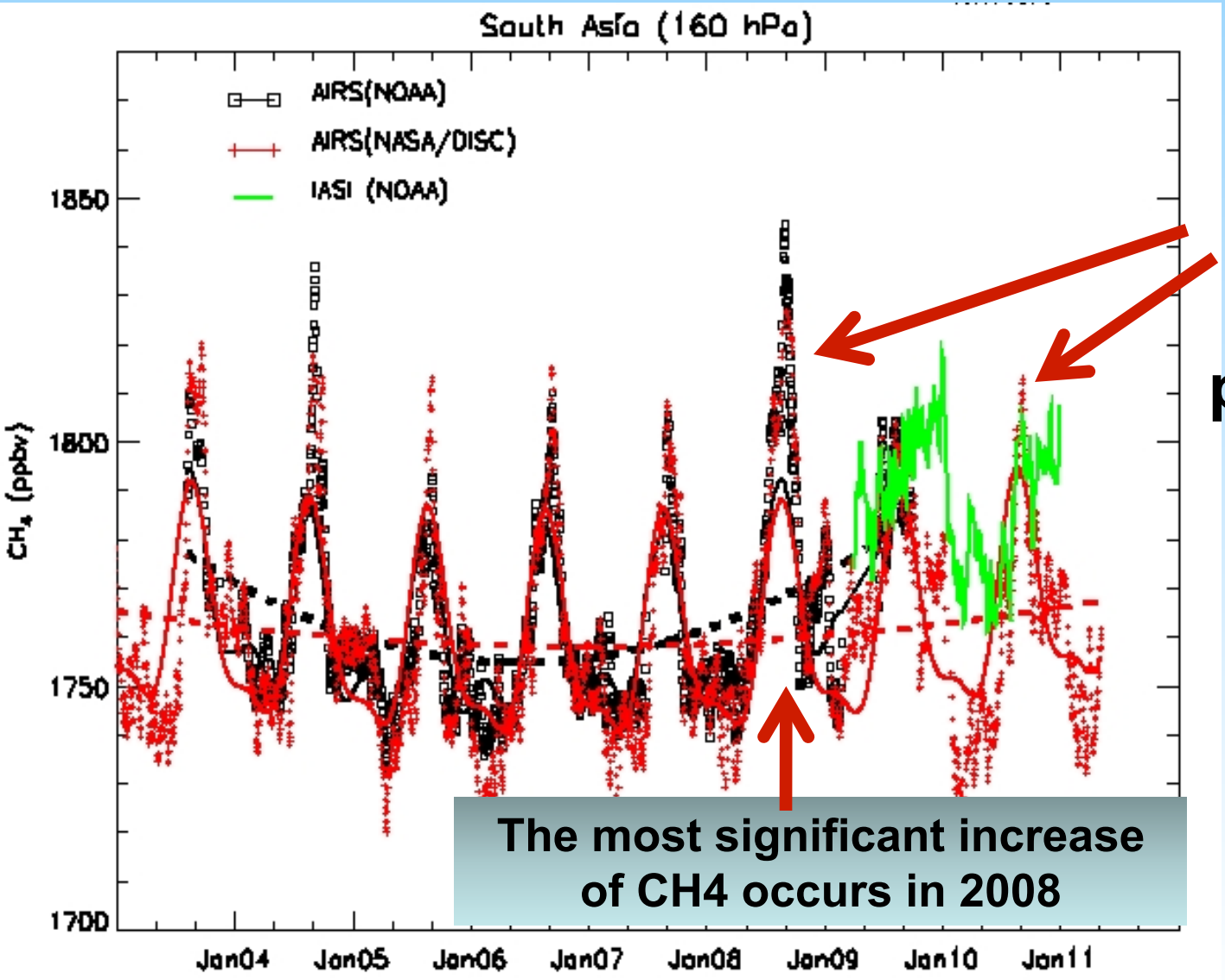
AIRS →



CH4 trend over Alaska-Canada - HNH

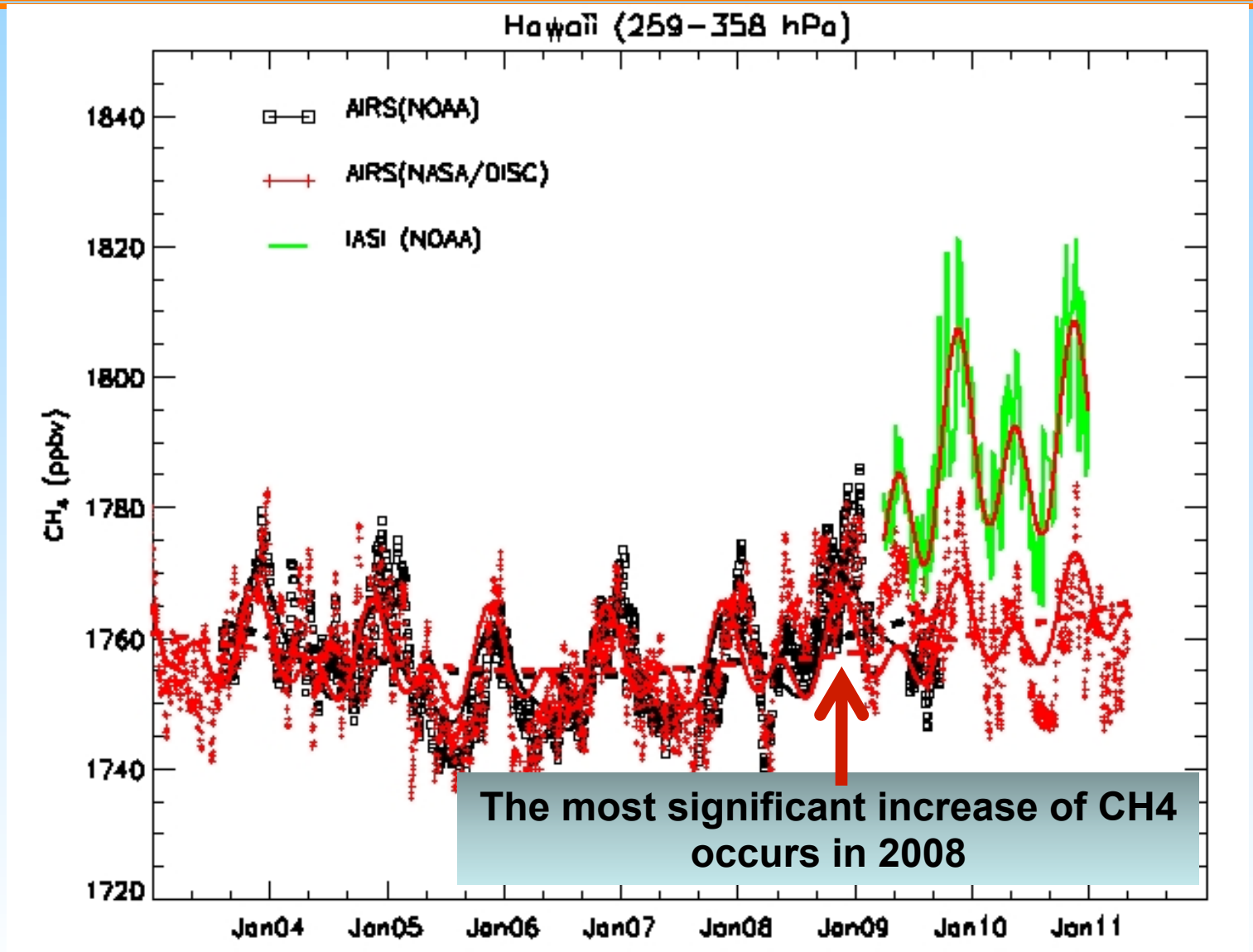


CH4 trend over south Asia



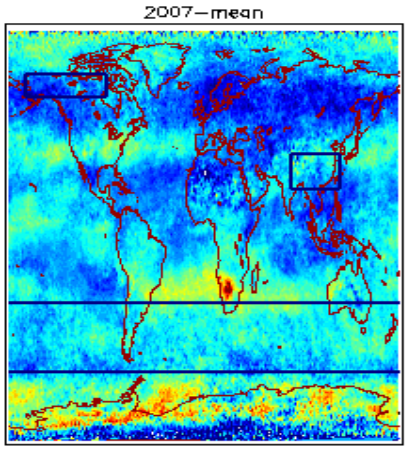
The plume has been seen in the past 9 years

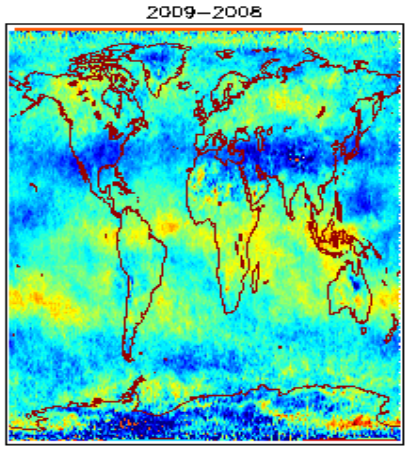
CH4 trend over Tropics



Annual increase in 2007,08,09

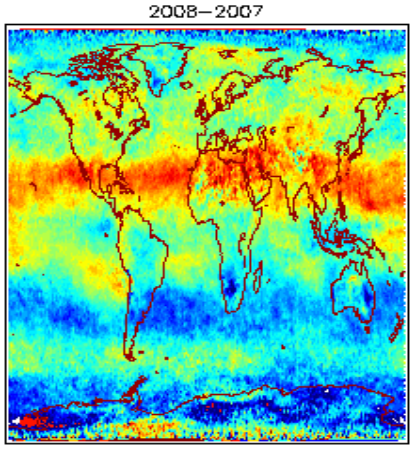
2007-2006

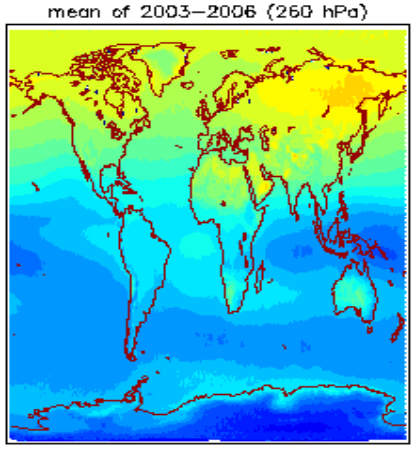




2009-2008

2008-2007





Mean of 2003 to 2006